Global Synoptic Diurnally Resolved Radiative Transfer Using CERES/MODIS and GEOSTATIONARY Satellite Observations

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SYNI Product What Is It?

- Hourly radiative transfer
  - UTC month (00Z day1 to 23z day 31)
  - Fu-Liou code
- CERES Equal Area grid (~1deg) n=44012
- TSI Cloud Inputs (Doelling Presentation)
  - CERES/MODIS(12hr),+GEO(3hr) + Interpolated
- MOA Geos_4.0.3 Atmosphere
  - SMOBA Ozone
- Modis & Match Aerosols
- Grid Average Surface properties
- *SYNI 1hourly is a CERES internal product*
  - *SYN a 3hourly product will be released to public.*

LaRC Fu-Liou Broadband Radiative Transfer

- Gamma weighted 2-Stream (SW) , 2/4 Stream (LW) pristine multi-stream correction to COART
  - Treats sub-computational scale Inhomogeneous clouds (S.Kato)
- Correlated k : 32 Bands : 18 SW, 14 LW , 3 of 14 LW in WN
  - Enhanced output of PAR and UVA,UVB (W.Su)
- Shortwave: (0.17 - 4.0 or *inf*)μ [0 or 2500-57000 cm-1]
  - HITRAN 2000 (H_20) w/(O_2,CO_2,CH_4)@Fixed concentration
  - JPL(1994) O_3 uv , WMO(1985) O_3 vis
- Longwave (0-2850cm-1) (3.5μ – Infinity)
  - H_20 ,CO_2 ,O_3 ,N_20 ,CH_4 ,CFCs, H20 continuum)
- Optical Properties: spectral (β, ω , g)
  - Water Cloud (Y.Hu)
  - Ice Cloud (Q.Fu 1996 ,Dge)
  - Aerosol Optical Properties
    - OPAC, Tegin&Lacis, d'Almedia
- Major Revisions
  - 10 visible SW bands reworked for O_3 and rayleigh in 1995
  - Near-Ir 0.7-1.3μ subdivided into 4 bands in 2005
- Online Version http://www-cave.larc.nasa.gov/cave

SYNI Surface Optics

- **Scene Id**:
  - IGBP
  - Daily Snow Ice maps (NSIDC microwave)
  - Threshold of Cloud WG Daily 0.63μ & 1.6μ overhead sun albedo
- **Broadband Surface Albedo:**
  - COART ocean surface albedo via look up table
    - (tau, solar zenith angle, wind speed)
  - Clear land+snow
    - CERES TOA with LaRC Fu-Liou atmosphere correction LUT
      - Clear sky CERES monthly mean is the input (NOT Geo)
  - Cloudy land: monthly minimum clear sky albedo retrieval
    - Diurnal model to diffuse angle
- **Spectral Albedo Shape**
  - COART (Ocean,Snow,Sea Ice)
  - CARE Experiment (grassland), Bowker (all other IGBP types)
- **Emissivity**
  - Cloud WG 12 month seasonal maps (3 window bands)
  - SOFA (IGBP based for other LW bands)

Surface Broadband Albedo Assignment

<table>
<tr><th></th><th>Clear Sky</th><th>Cloudy Sky
Tau < 20</th><th>Cloudy Sky
Tau>20</th></tr>
<tr><td>Ocean</td><td colspan="3">COART based LUT (apriori)</td></tr>
<tr><td>Snow / Ice</td><td rowspan="2">TOA based
(Clear method)</td><td>TOA (Cld method)
Consistency w/Cloud</td><td>Sfc Alb History</td></tr>
<tr><td>Land</td><td>Sfc Alb History</td><td>Sfc Alb History</td></tr>
</table>

SYNI Aerosols

- MODIS (MOD04)
  - multi-channel AOT (7 wavelength ocean, 3 land)
  - Temporally interpolated from Clear sky observations
- MATCH Daily Assimilation
  - Constituents
    - Small & Large Dust, Sea Salt, Sulfate, Black Carbon, Hydrophilic & Hydrophobic organic carbon
    - Basis for assignment of optical properties (β,ω,g)
      - Tegin&Lacis , OPAC
    - MATCH optical depth used over high albedo land
  - Vertical profiles

Ultraviolet : UVA, UVB, UV Index

- Output of Surface UVA , UVB and UV Index.
- Fu-Liou (.2985 – .3225) and (.3225 - .3575) micron bands do not match UVA(.32-.40) and UVB(0.29-0.32)
- With only one absorption K in Fu-Liou(.2985 – .3225) accuracy of small magnitude flux an issue
- W.Su used SBDART to produce coefficients for a ratio correction factor to produce UVA,UVB,UVIndex from current Fu-Liou spectral outputs.
  - Function(Ozone, Sza,sfcalb,abs Aot) ! CLEAR SKY
  - Function(Ozone,Sza, cld tau, cld height) !Cloudy Sky

Tuning Overview

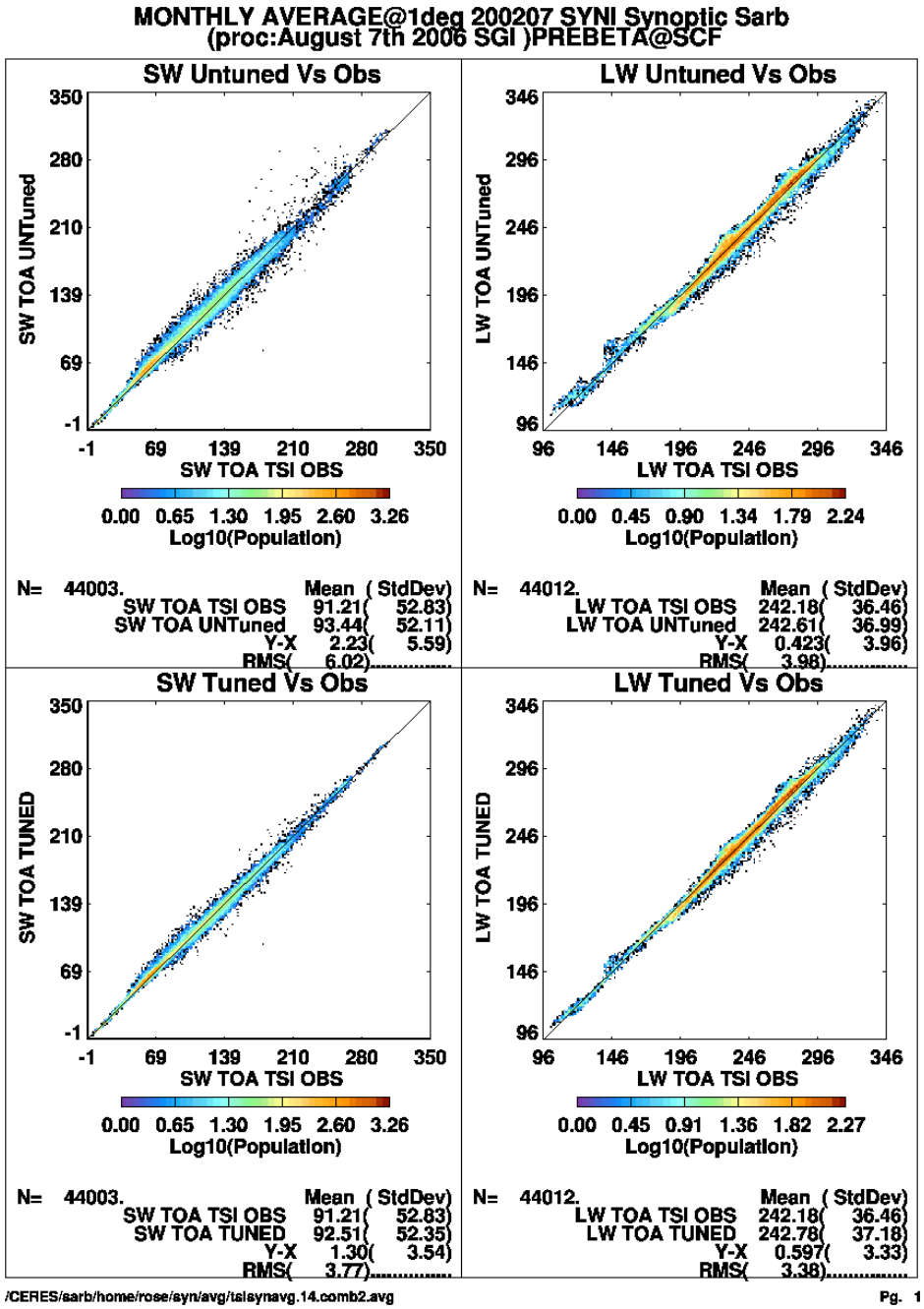
- Adjust inputs of
  - Clear Sky (PW, UTH, Aerosol Optical Depth, SfcAlb)
  - Total Sky (Cloud [Fraction, Optical Depth , Height])
- Assignment of 1σ uncertainty of inputs and flux obs
- Pre-computed partial derivatives
  - ΔSW & ΔLW as functions of input tuning variables
  - For a large set and range of state conditions
- Minimize: Flux error (ε) and input adjustments (δ)

$$(\varepsilon_{sw}/\sigma_{sw})^2 + (\varepsilon_{Lw}/\sigma_{Lw})^2 + (\delta_{pw}/\sigma_{pw})^2 + (\delta_{uth}/\sigma_{uth})^2 + (\delta_{aot}/\sigma_{aot})^2 + (\delta_{sfca}/\sigma_{sfca})^2 + (\delta_{sfca}/\sigma_{sfca})^2 + (\delta_{frac}/\sigma_{frac})^2 + (\delta_{tau}/\sigma_{tau})^2 + (\delta_{hgt}/\sigma_{hgt})^2$$

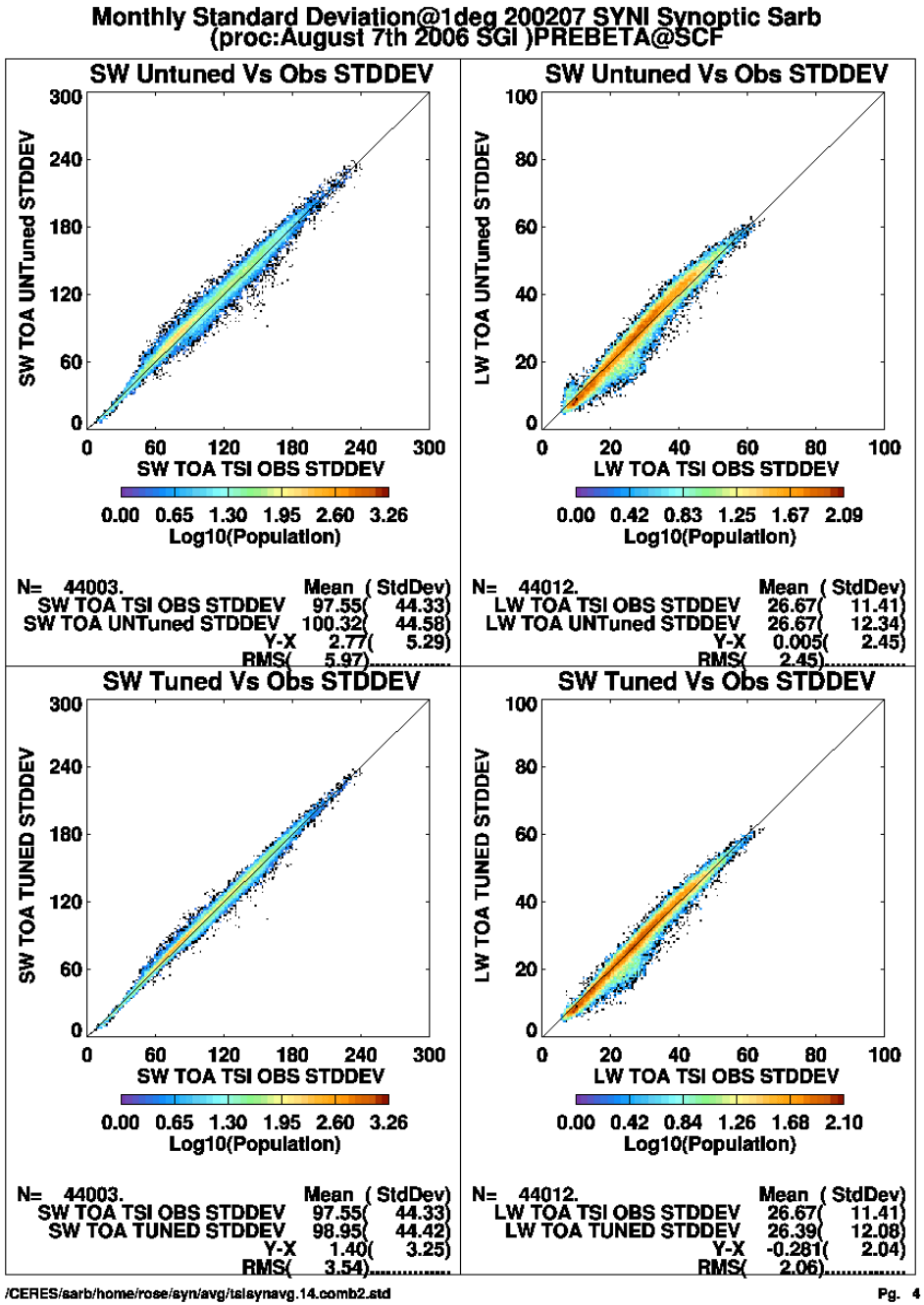
RESULTS
Single Month of July 2002

- Pre Beta SYNI Hourly product
  - Processed @SCF Aug 7th 2006
- Most of plots are NOT formal TISA “AVG”
  - (“AVG” Code Early November 2006)
  - Some of the first AVG product plots taken from TISA group (D.Doelling, C.Nguyen, D.Keyes)

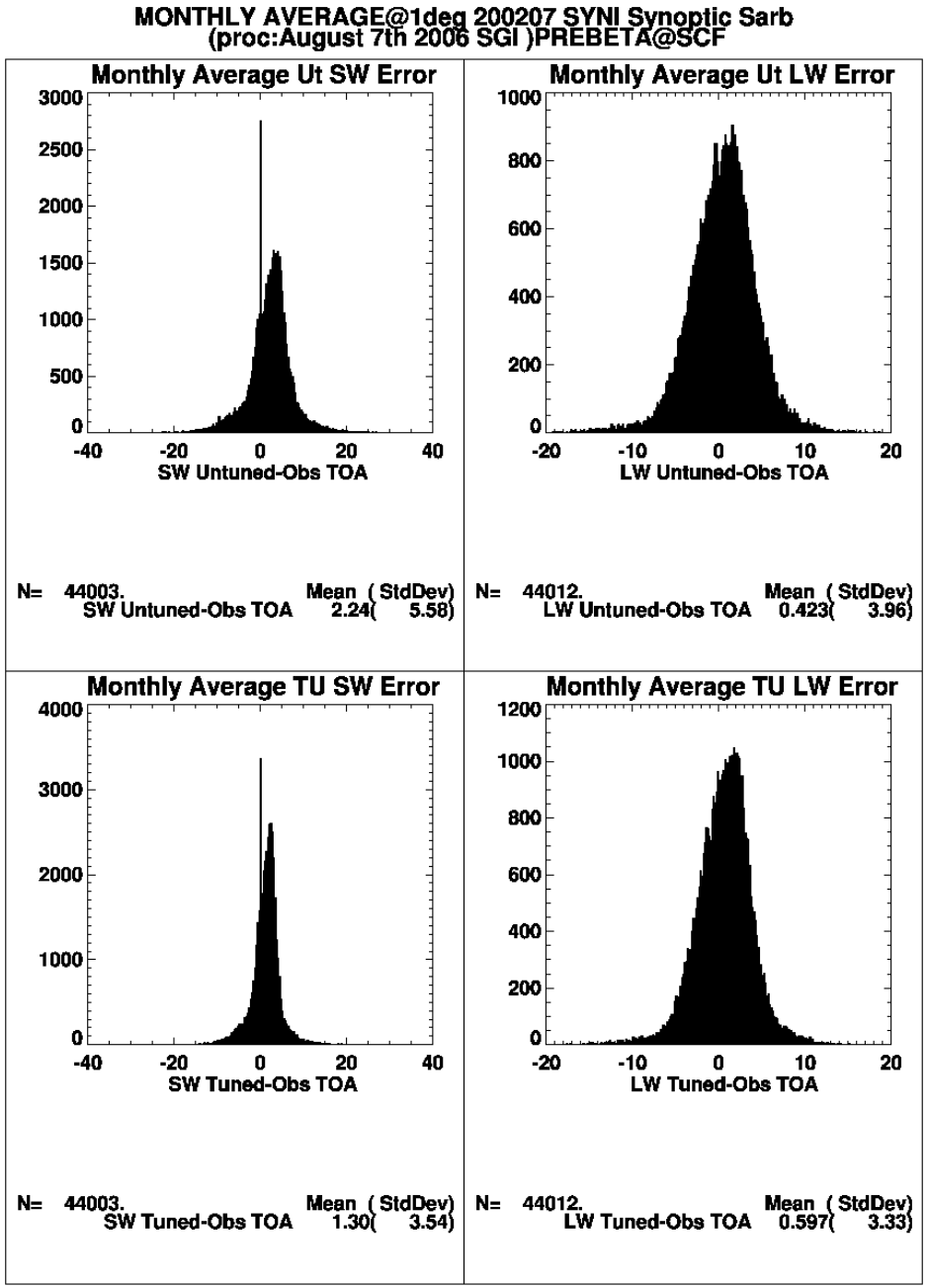
- Each point represents a gridbox monthly average over 744 hours
- Top of Atmosphere LW and SW
  - Untuned top
  - Tuned bottom



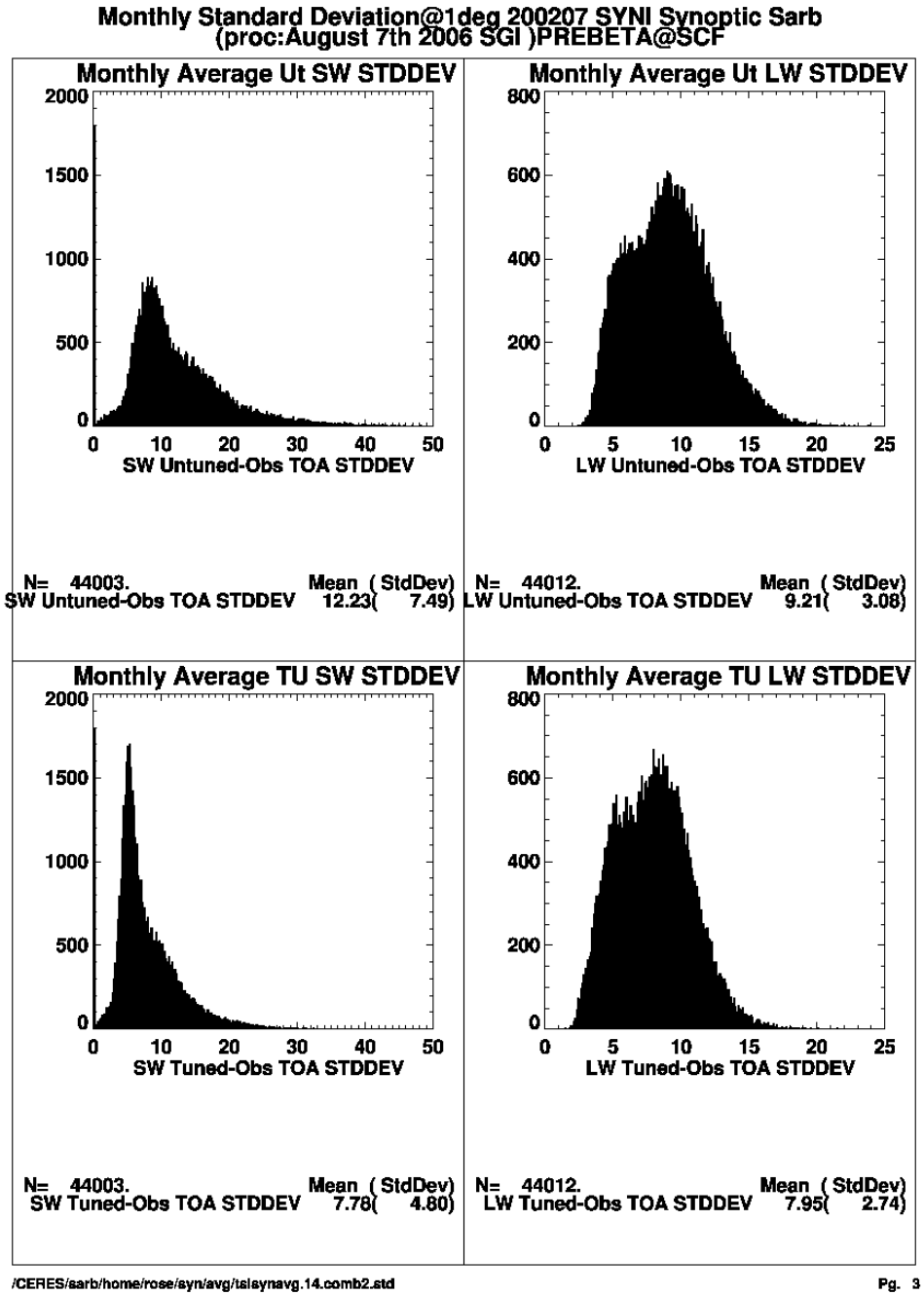
- Each point represents a gridbox monthly temporal standard deviation over 744 hours
- Temporal variability captured well by model using cloud inputs .



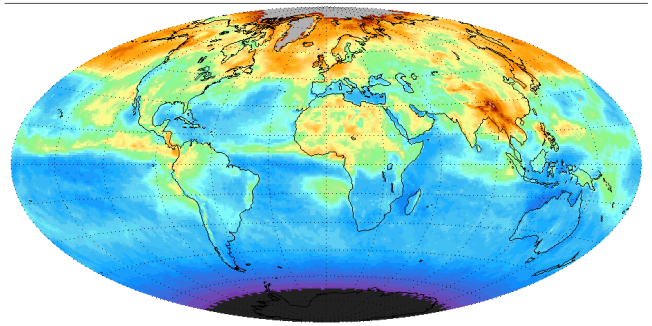
- Histograms of monthly mean TOA SW and TOA LW bias
  - Untuned top
  - Tuned bottom



- Histogram of standard deviation of model minus observed TOA SW & LW
- Highlights tuning processes with goal of reducing bias of instantaneous computations

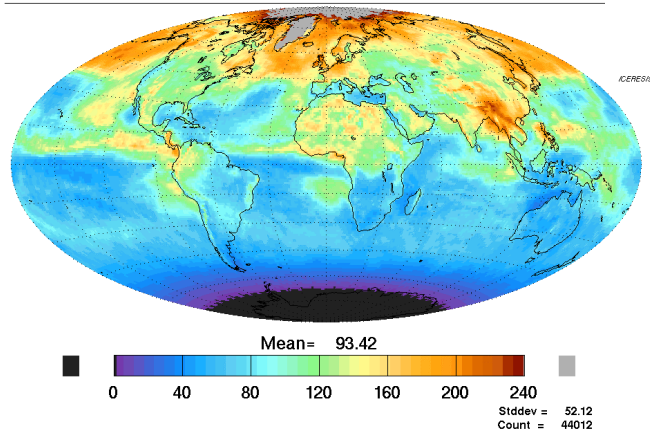


TSI 200207 Shortwave TOA Reflected
Total Sky Monthly Mean

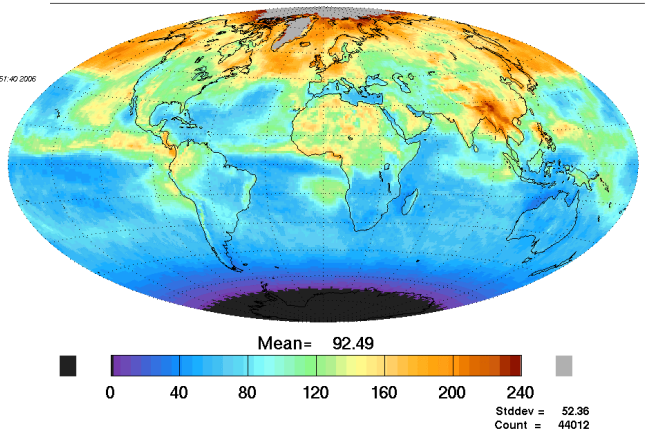


/CERES/larb/home/rose/synvavg/tsisynavg.14.com62.avg Wed Aug 9 10:51:40 2006

SYNI 200207 UNTuned Shortwave TOA Reflected
Monthly Mean

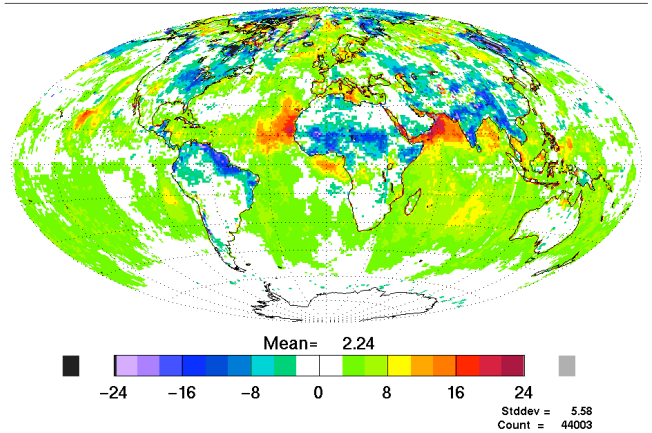


SYNI 200207 Tuned Shortwave TOA Reflected
Monthly Mean



SW TOA FLUX Observed = 92.21	
Untuned 93.42	Tuned 92.49
Untuned-Observed 2.24	Tuned-Observed 1.30

SYNI 200207 UNTuned–Obs Shortwave TOA Reflected
Monthly Mean



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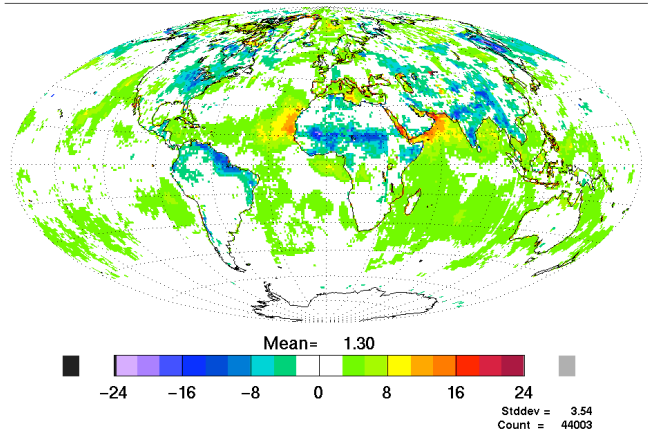
SYNI 200207 Tuned–Obs Shortwave TOA Reflected
Monthly Mean



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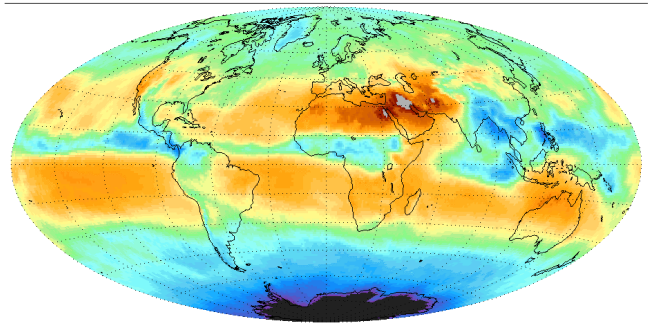
TSI 200207 Outgoing Longwave
Total Sky Monthly Mean



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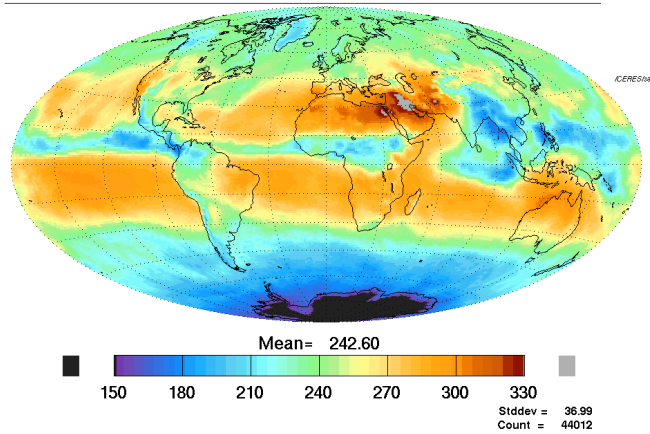
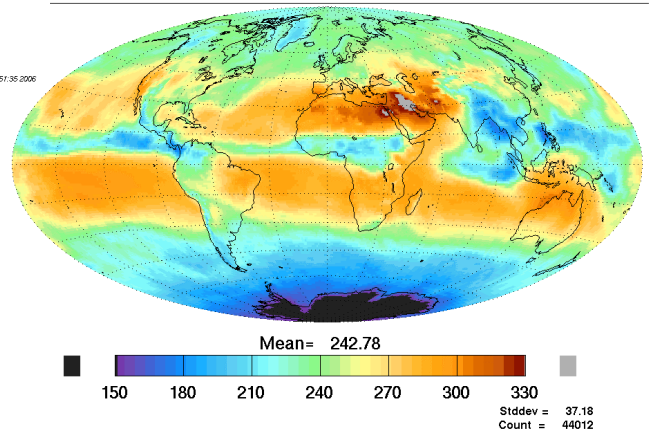
SYNI 200207 UNTuned Outgoing Longwave
Monthly Mean

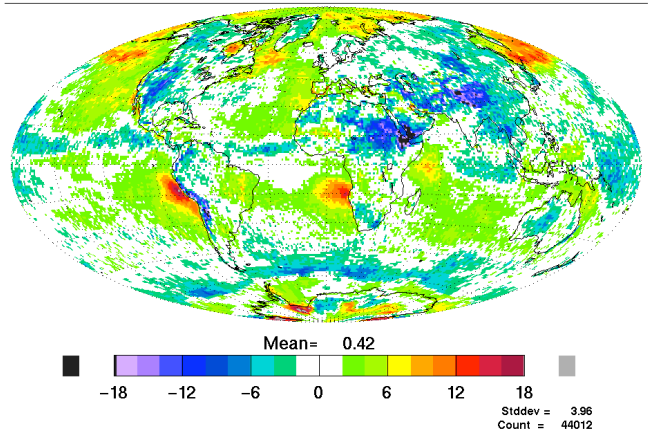


SYNI 200207 Tuned Outgoing Longwave
Monthly Mean



LW TOA FLUX Observed = 242.18	
Untuned 242.60	Tuned 242.78
Untuned-Observed 0.42	Tuned-Observed 0.60

SYNI 200207 UNTuned–Obs Longwave TOA
Monthly Mean



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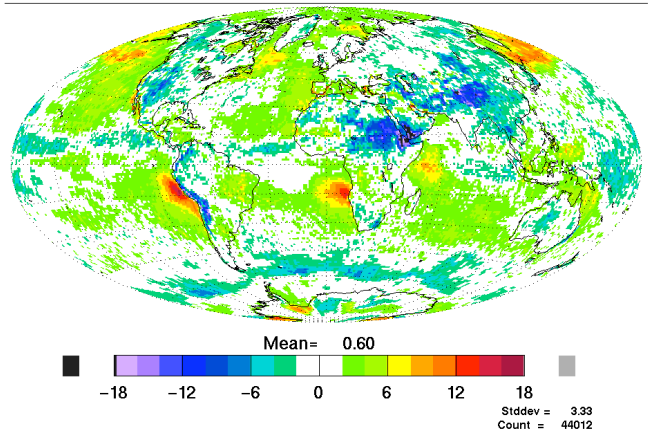
SYNI 200207 Tuned–Obs Longwave TOA
Monthly Mean



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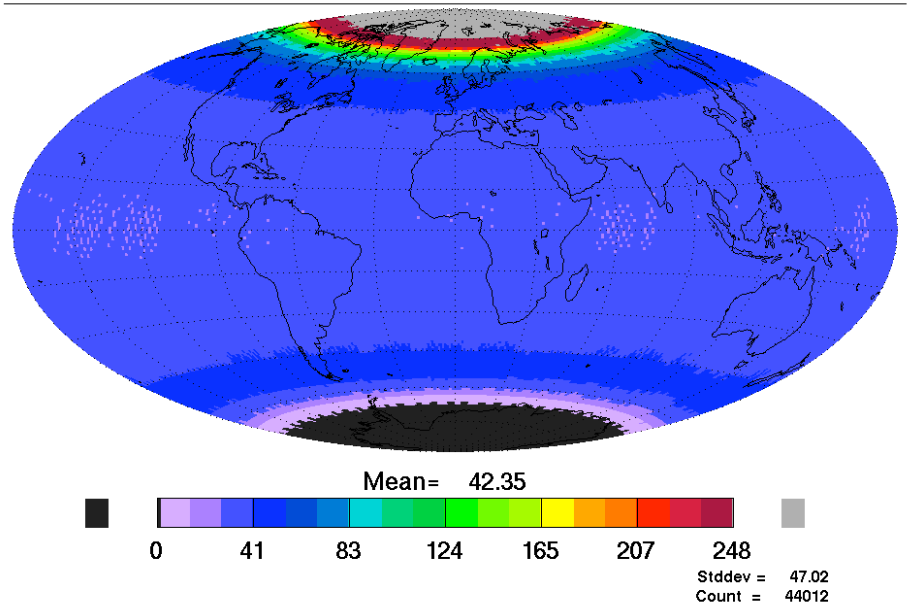
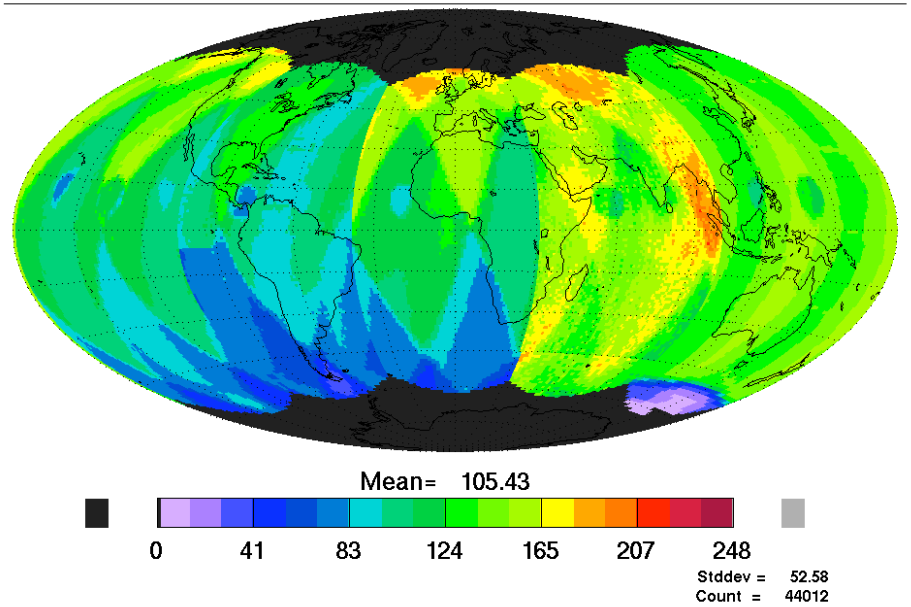
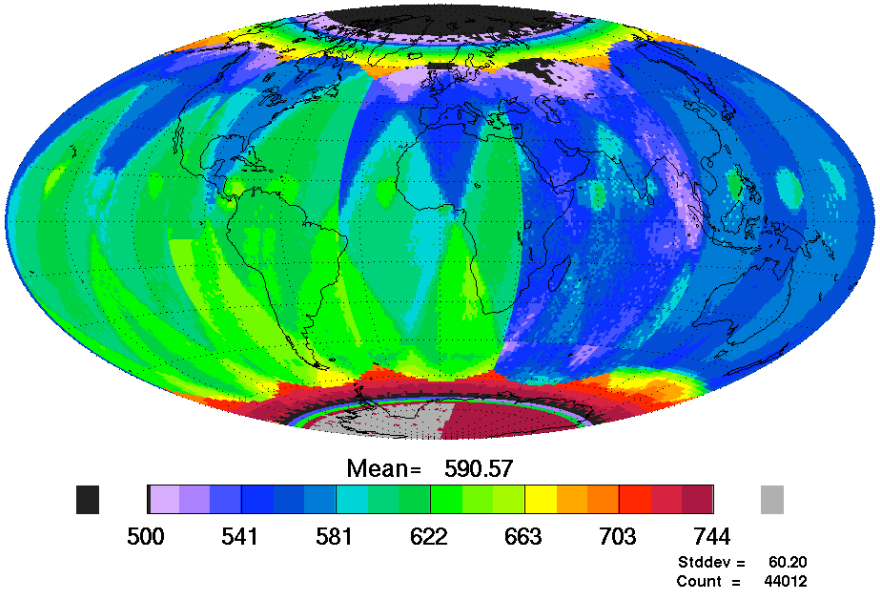
CERES Daytime Only



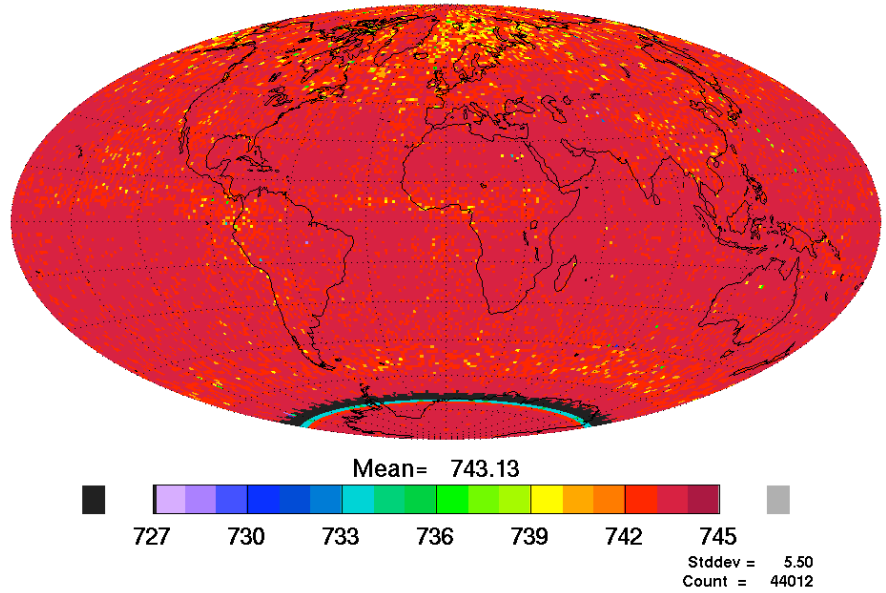
GEOSTATIONARY Daytime Only



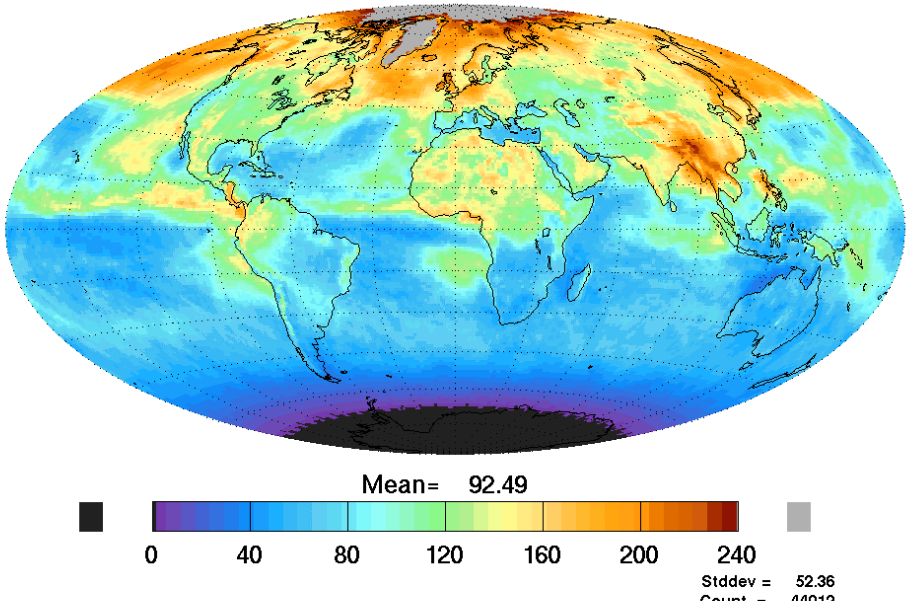
Interpolated Day&Nighttime



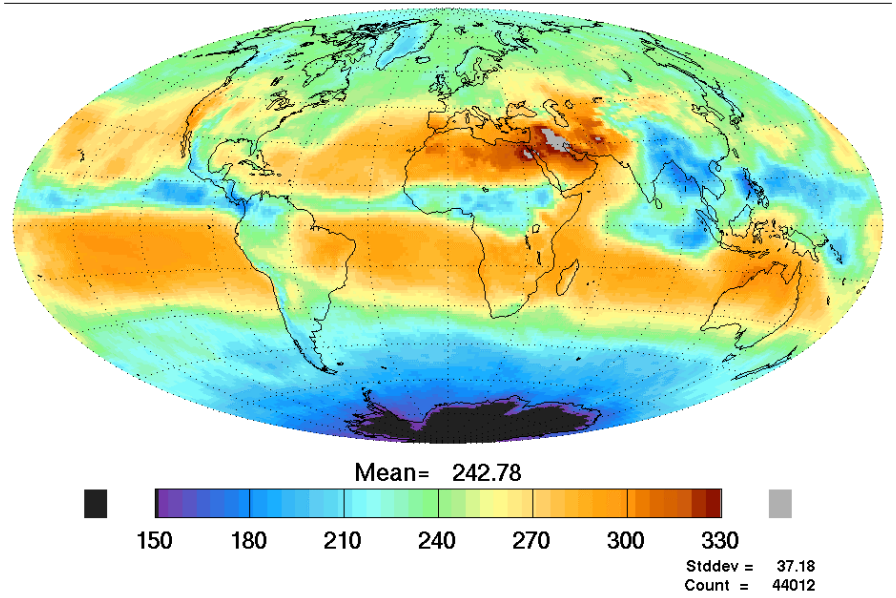
Any Valid Computation



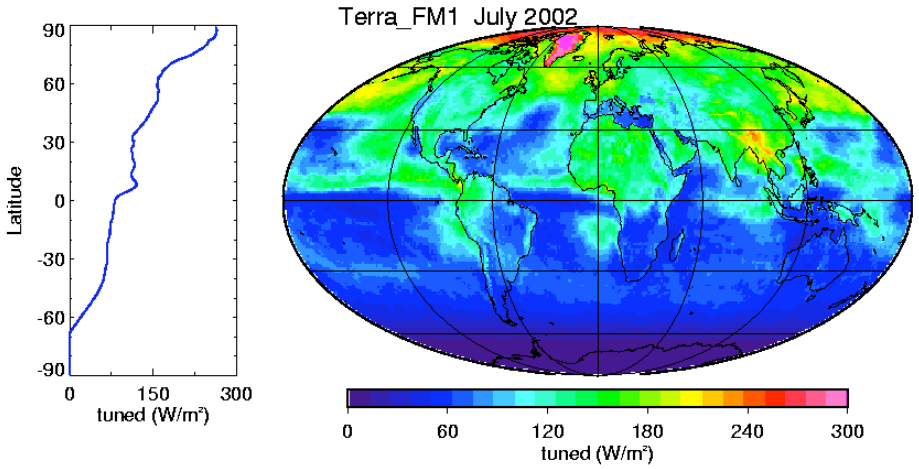
SYNI 200207 Tuned Shortwave TOA Reflected Monthly Mean



SYNI 200207 Tuned Outgoing Longwave Monthly Mean



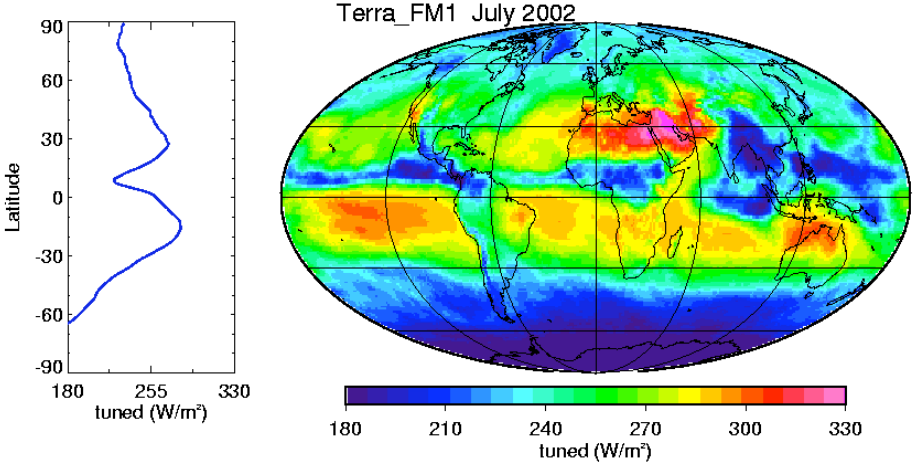
TISA "AVG" tuned All-sky TOA Shortwave Rev1 Flux



Global tuned 93.4

SRBAVG1 FILE: CER_SRBAVG1_Terra-FM1-MODIS_Edition2D_016028.200207

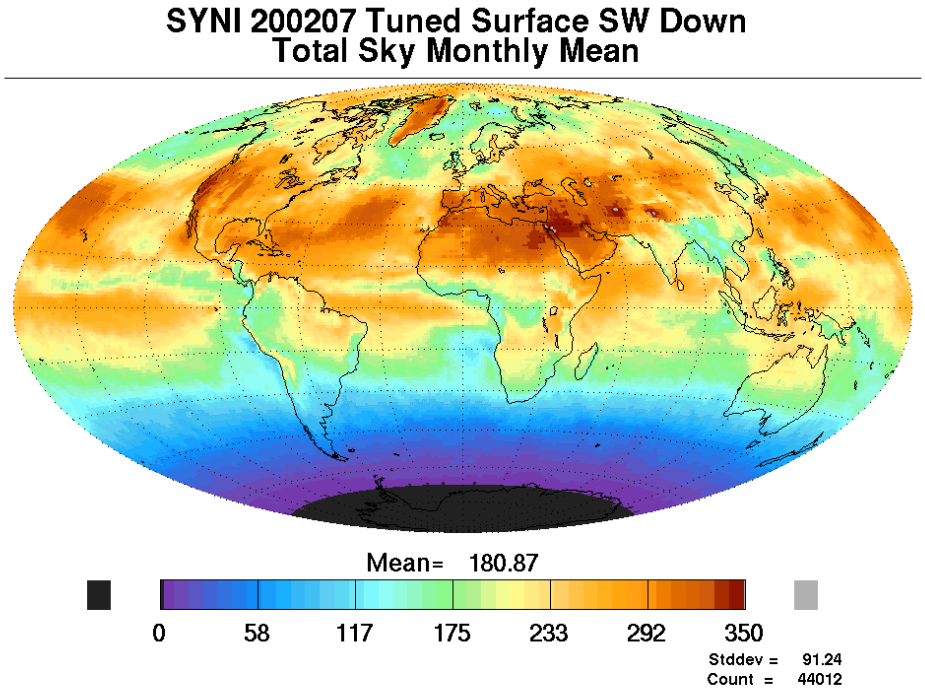
TISA "AVG" tuned All-sky TOA Longwave Flux

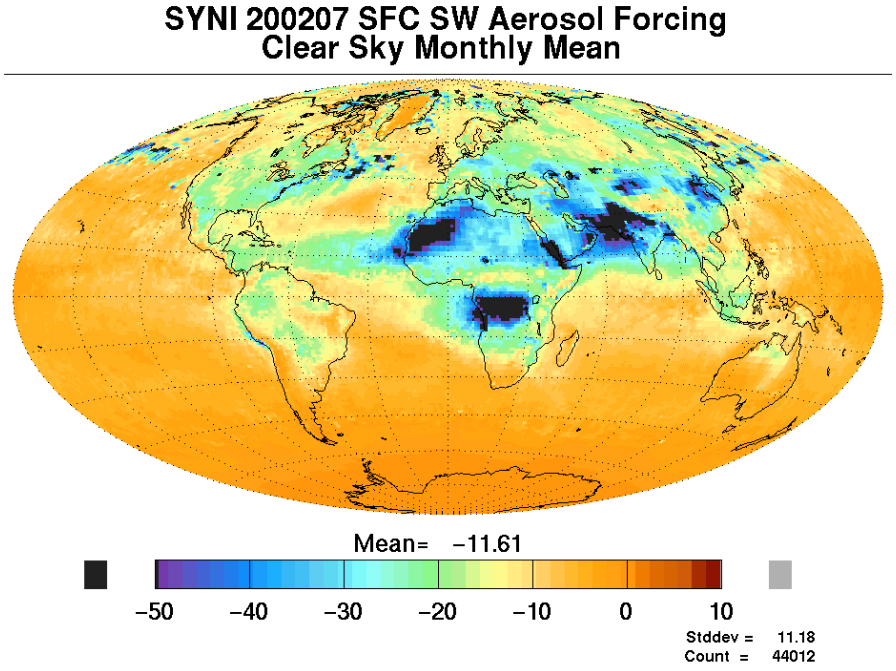


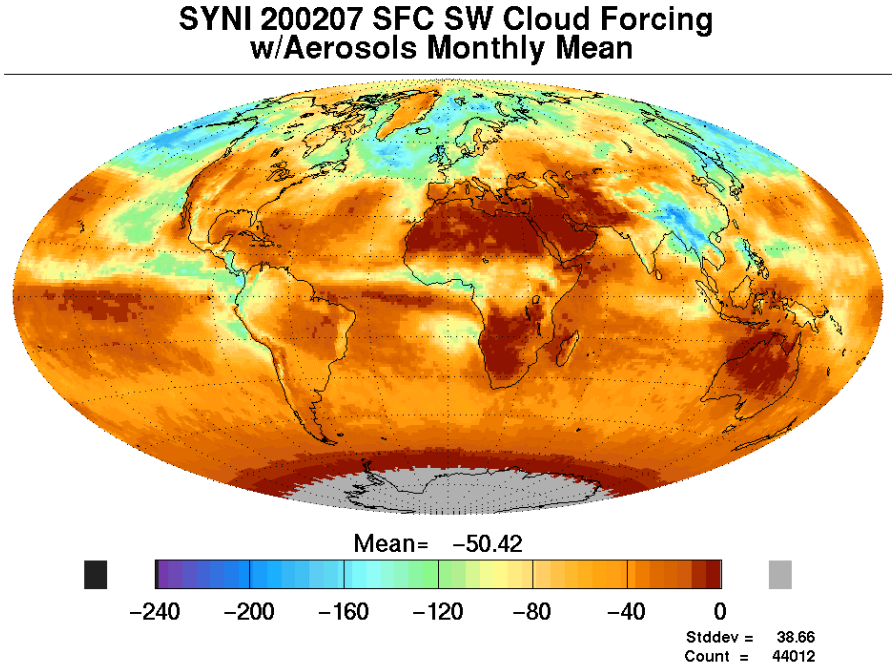
Global tuned 242.6

SRBAVG1 FILE: CER_SRBAVG1_Terra-FM1-MODIS_Edition2D_016028.200207

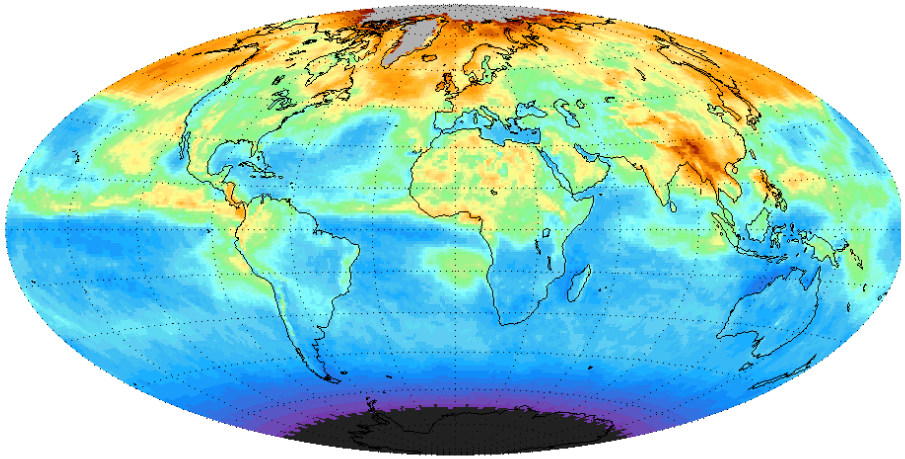
- Surface&TOA Forcings
  - Pristine Sky NO Aerosol
  - Clear Sky
  - Total Sky NO Aerosol
  - Total Sky







SYNI 200207 Tuned Shortwave TOA Reflected Monthly Mean

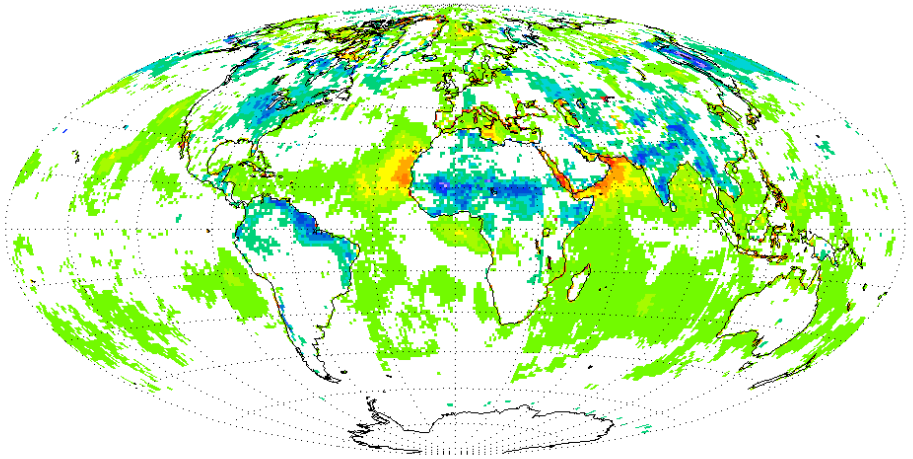


Mean= 92.49

0 40 80 120 160 200 240

Stddev = 52.36
Count = 44012

SYNI 200207 Tuned−Obs Shortwave TOA Reflected Monthly Mean

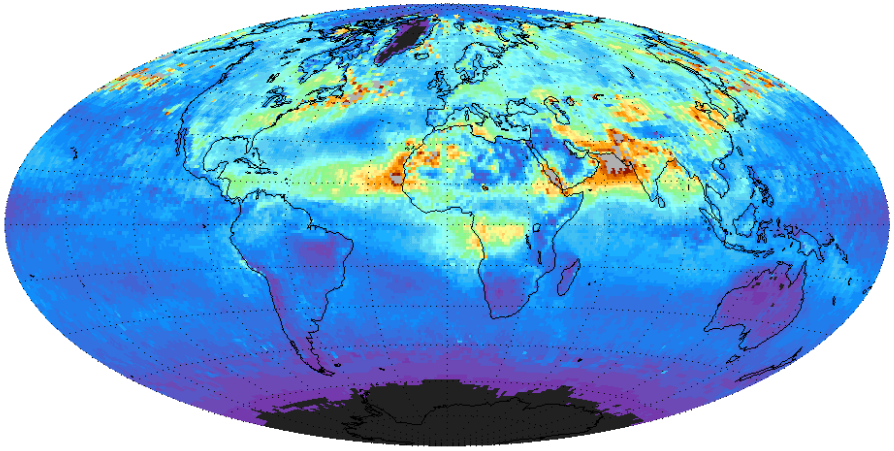


Mean= 1.30

−24 −16 −8 0 8 16 24

Stddev = 3.54
Count = 44003

SYNI 200207 TOA SW Aerosol Forcing Clear Sky Monthly Mean

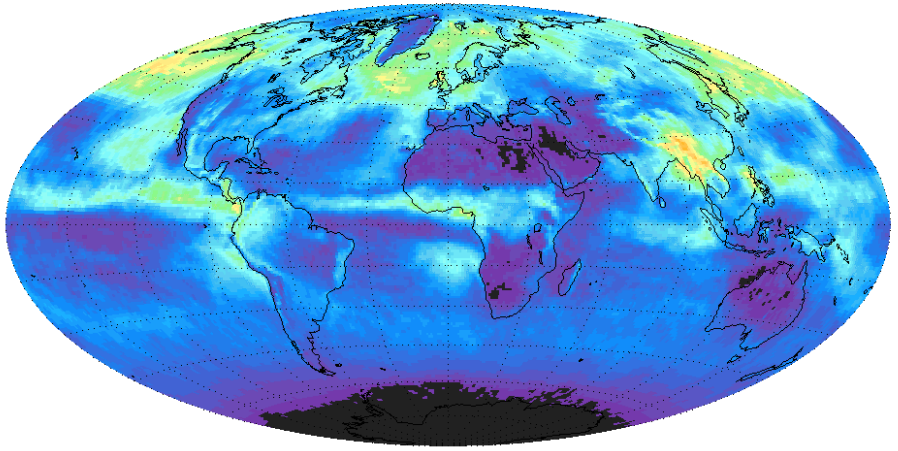


Mean= 6.47

0 5 10 15 20 25 30

Stddev = 5.50
Count = 44012

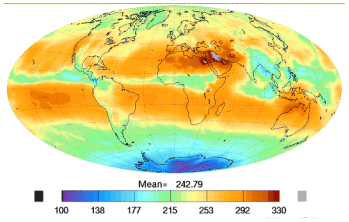
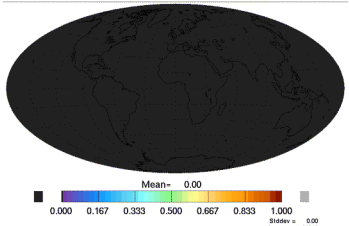
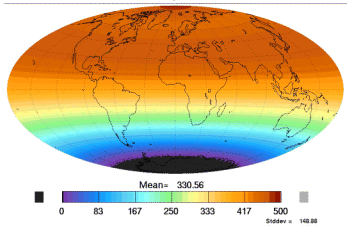
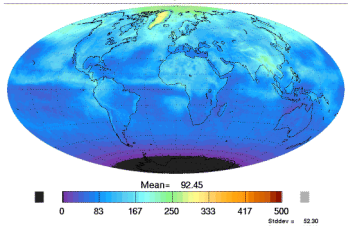
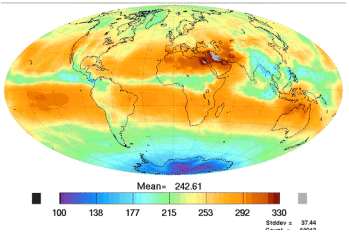
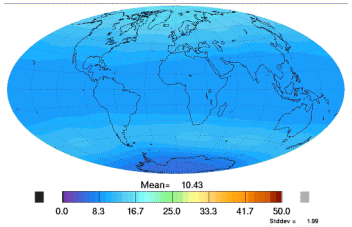
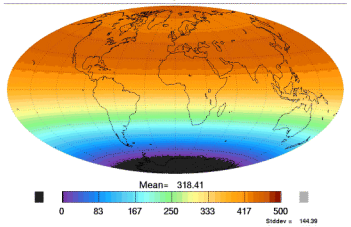
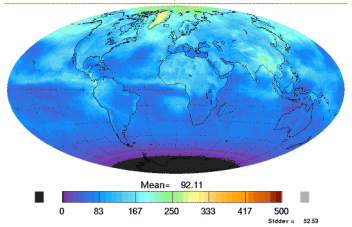
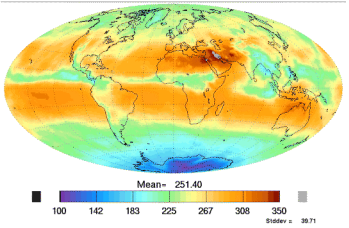
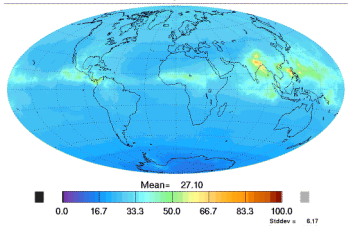
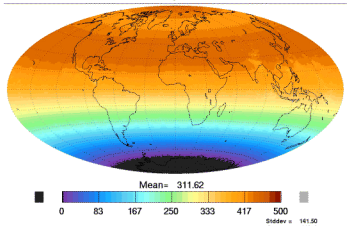
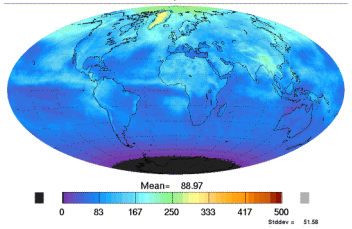
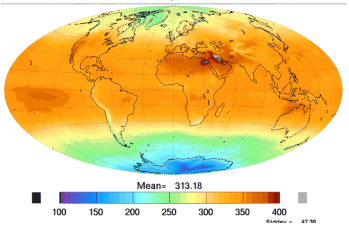
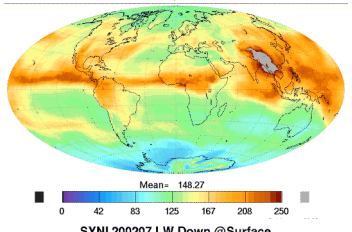
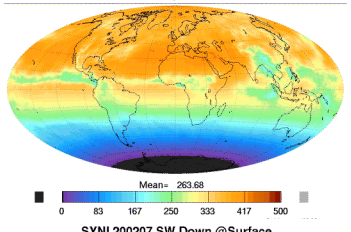
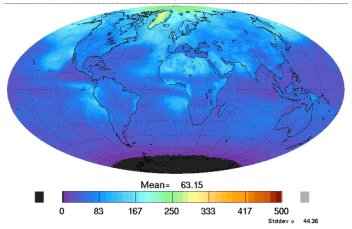
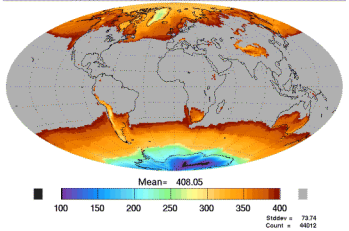
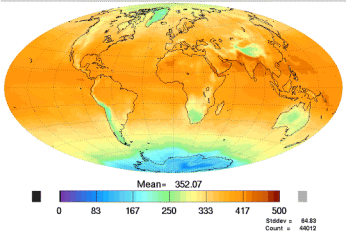
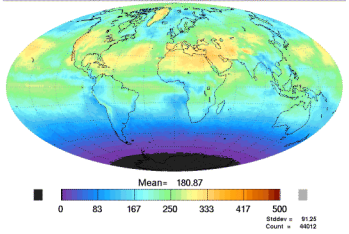
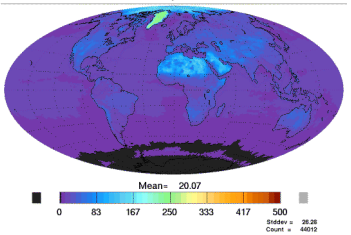
SYNI 200207 TOA SW Cloud Forcing Clear Sky Monthly Mean



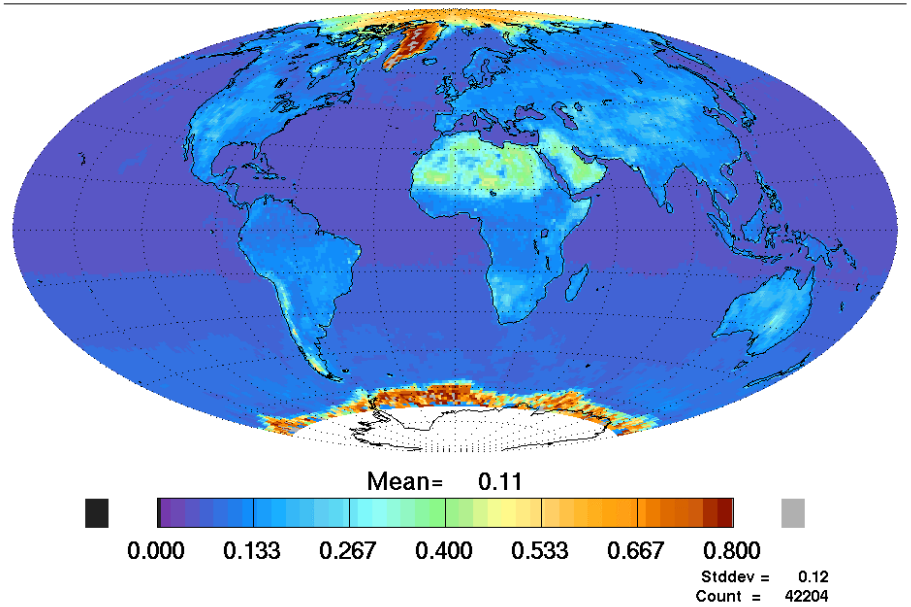
Mean= 44.01

0 40 80 120 160 200 240

Stddev = 33.68
Count = 44012

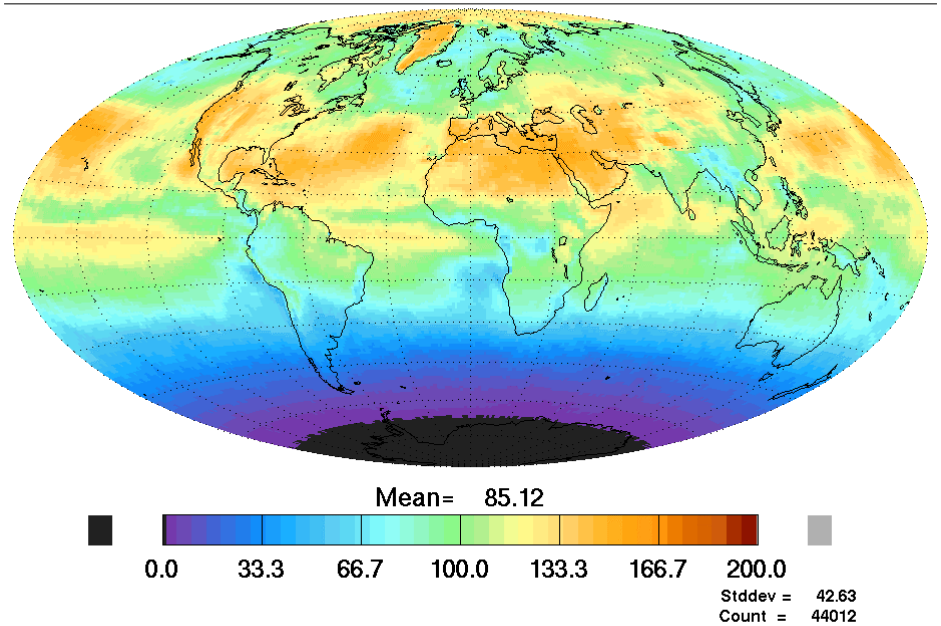
	LW Up	LW Down	SW Down	SW Up
TOA				
70				
200				
500				
SFC				

SYNI 200207 UNTuned Surface Albedo



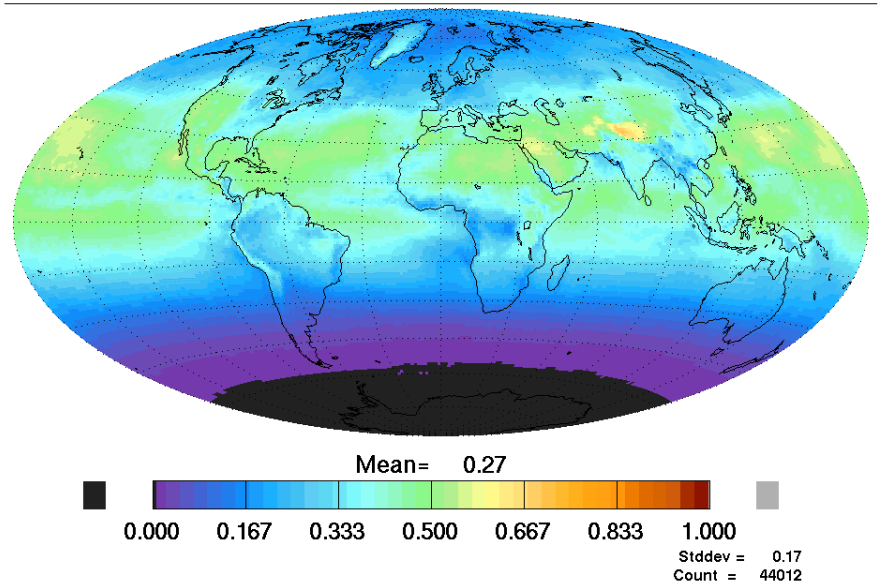
06

SYNI 200207 PAR SW SFC
Monthly Mean



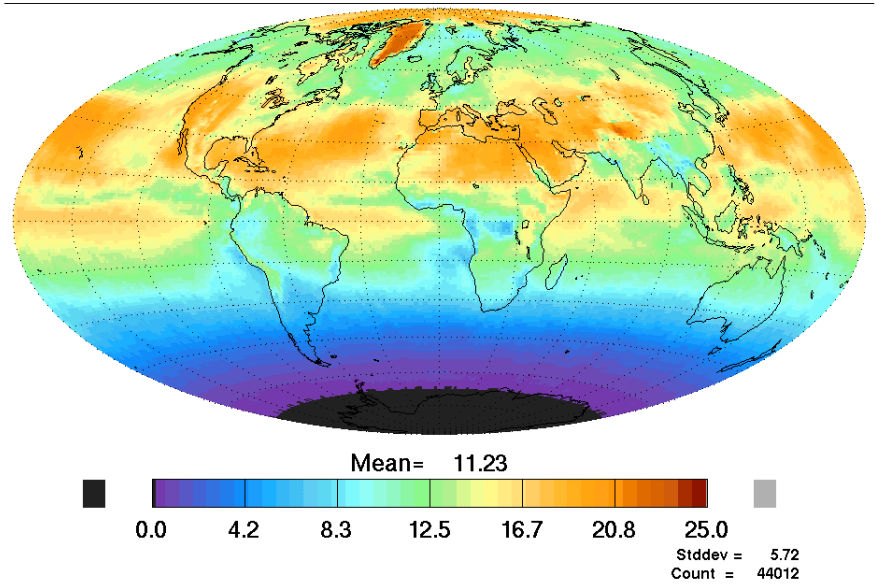
1 2006

SYNI 200207 UVB SW SFC
Monthly Mean



/CERES/sarb/home/rose/syn/avg/tsisynavg.15.avg Fri Aug 11 12:41:24 2006

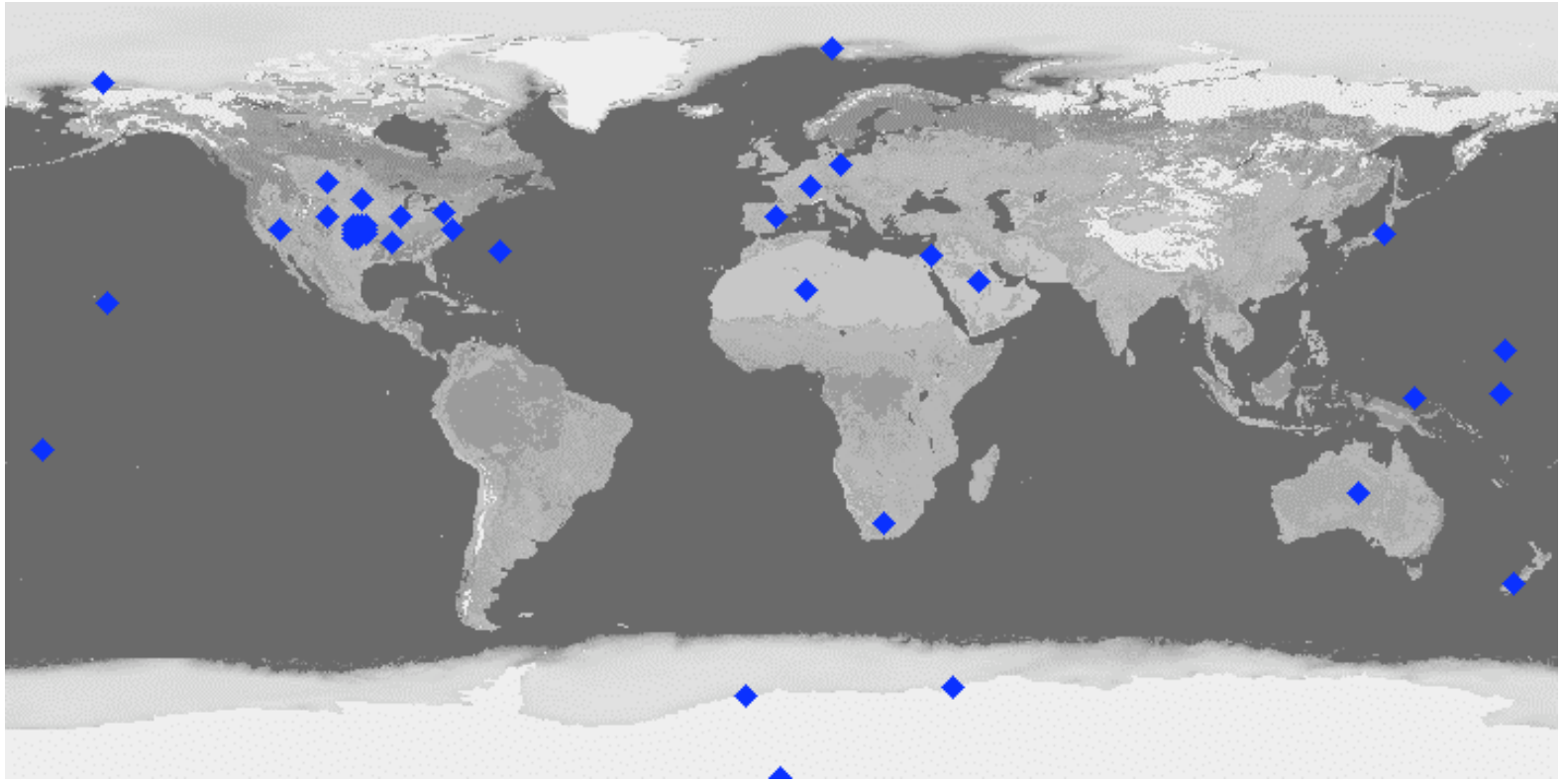
SYNI 200207 UVA SW SFC
Monthly Mean



/CERES/sarb/home/rose/syn/avg/tsisynavg.15.avg Fri Aug 11 12:41:28 2006

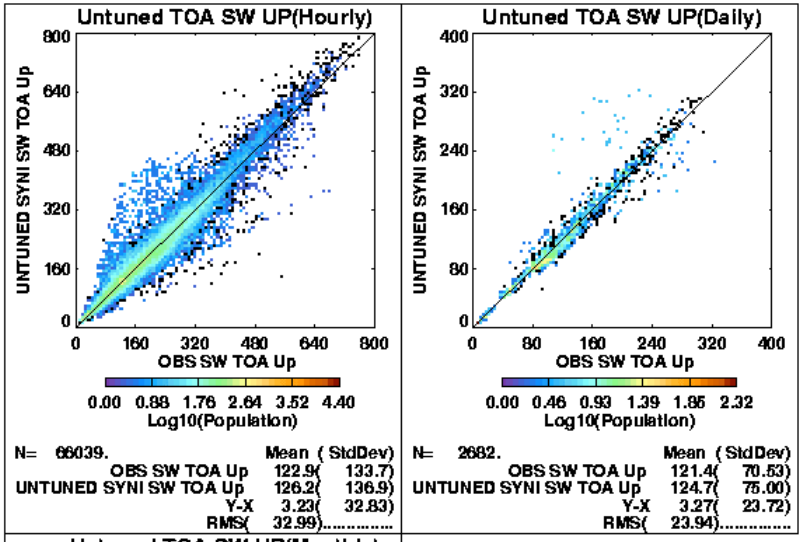
Surface Flux Validation

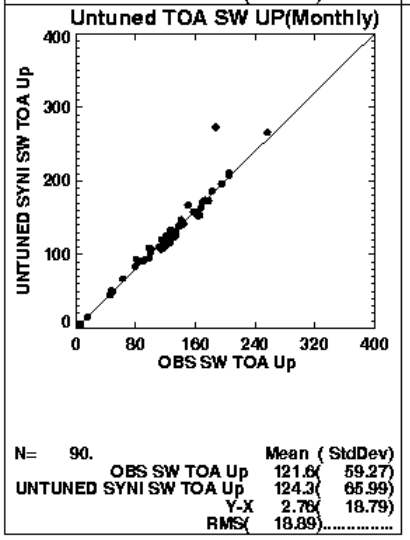
- 44 CAVE Surface Sites , July 2002
  - Hourly (744x44) &Daily (31x44) & Monthly(44)

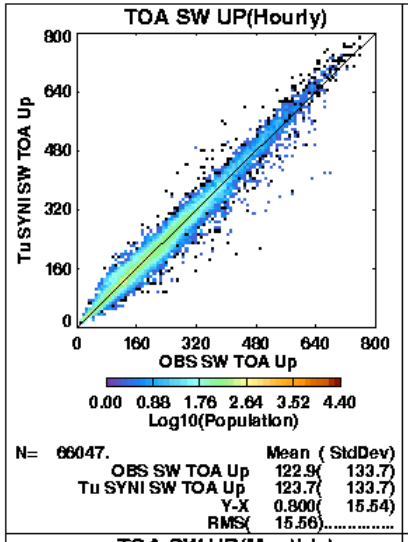


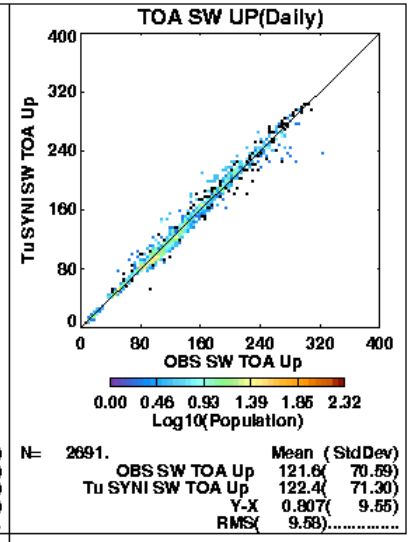
Validation 44 Site SW TOA

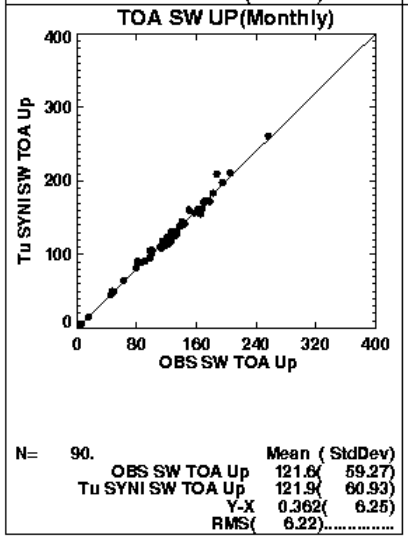
Hourly ,Daily , Monthly (Untuned& Tuned)





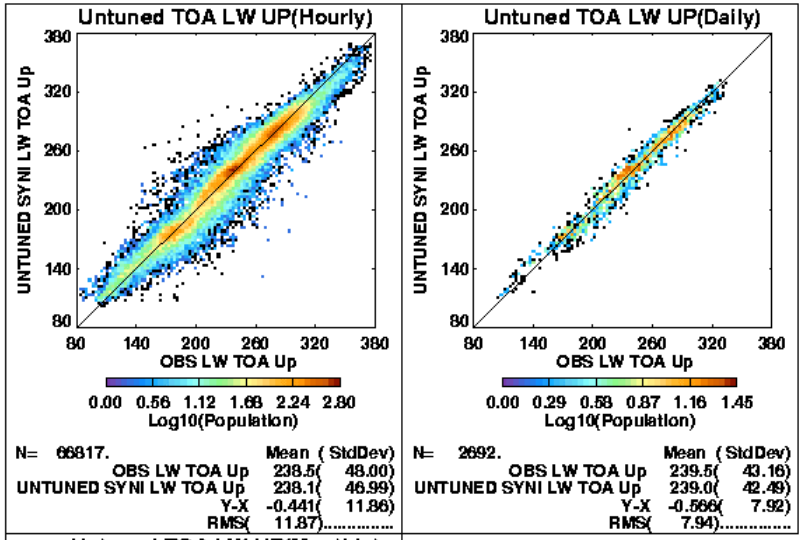


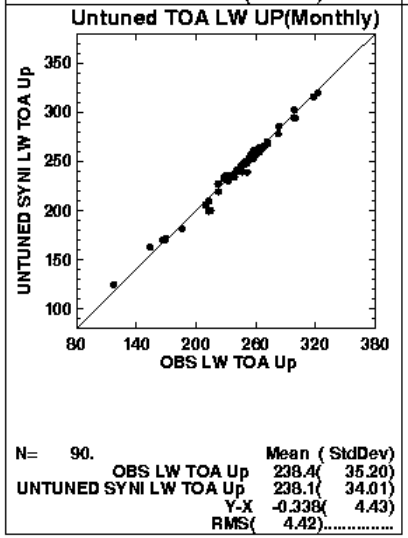


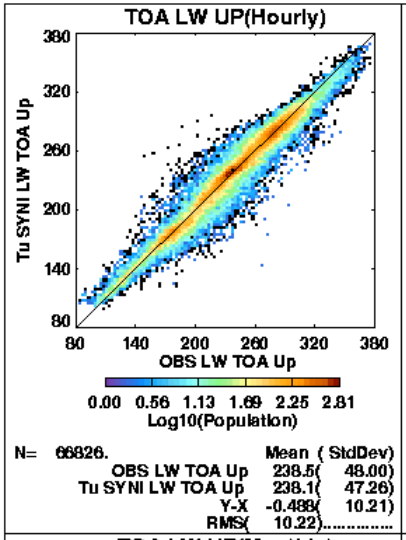


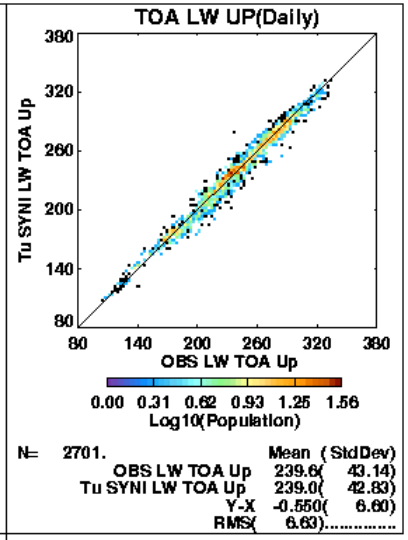
Validation 44 Site LW TOA

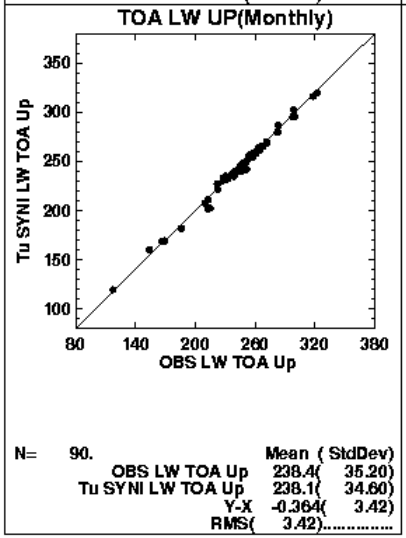
Hourly ,Daily , Monthly (Untuned& Tuned)





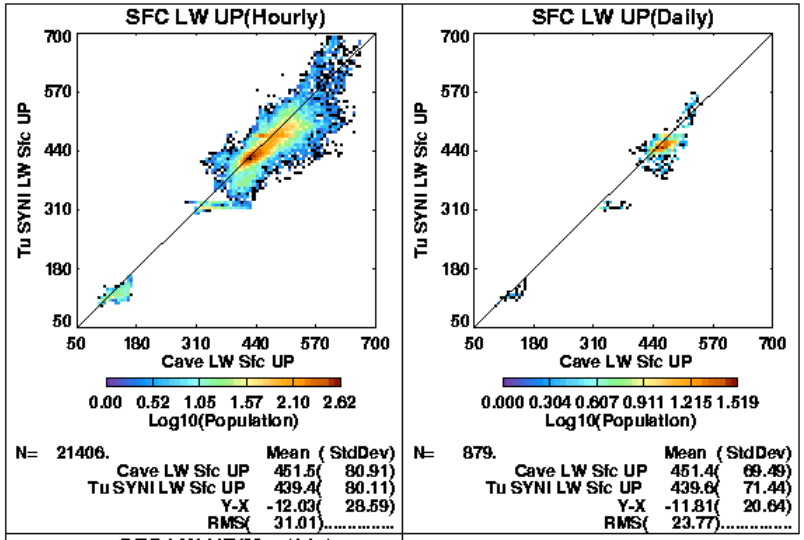


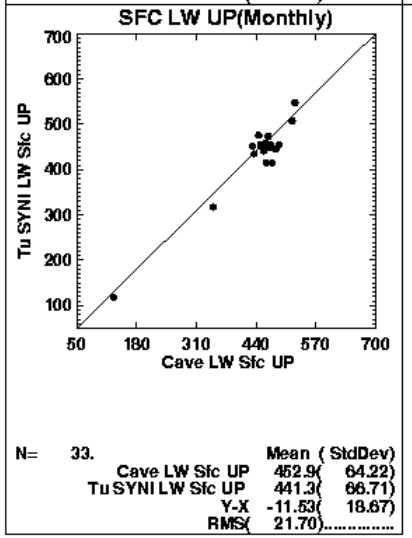


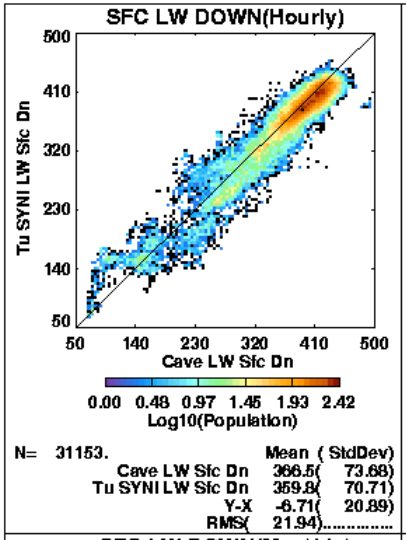


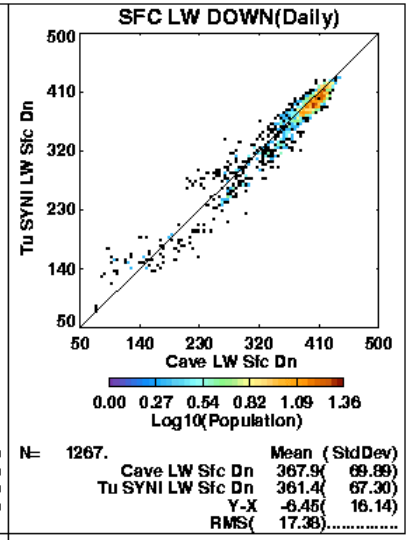
Validation 44 Site SFC LW

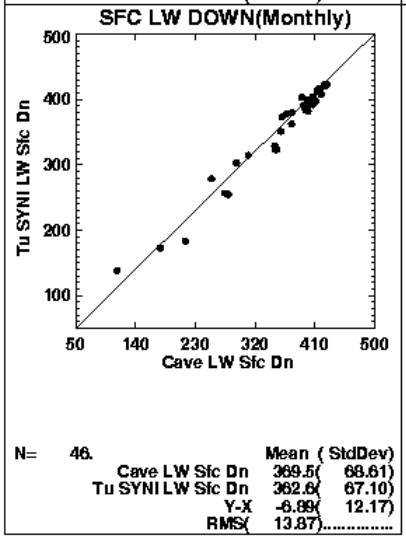
Hourly ,Daily , Monthly (Tuned)





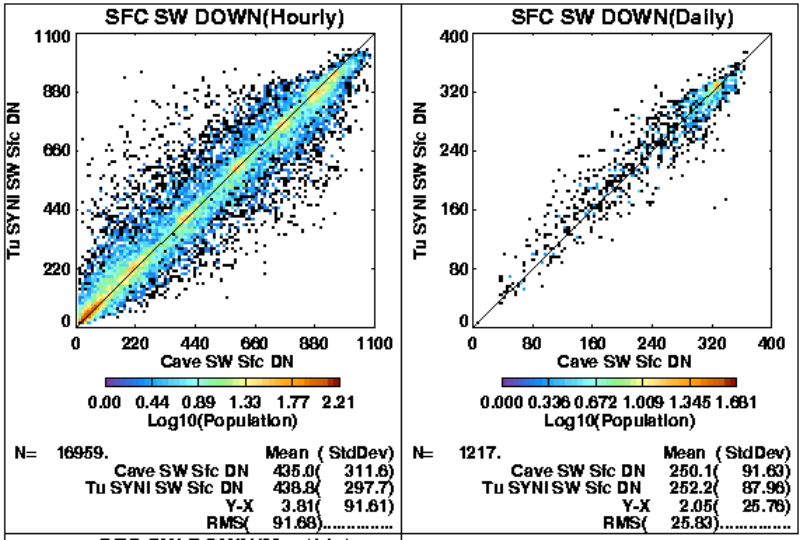


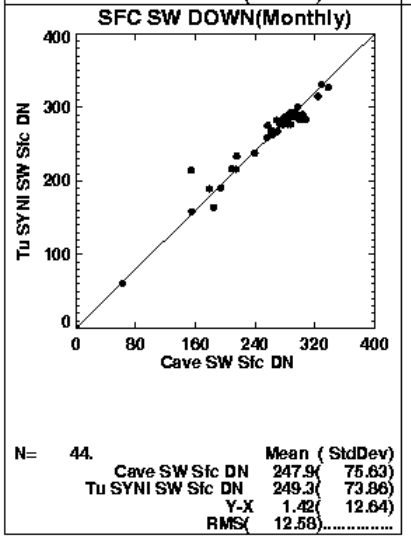


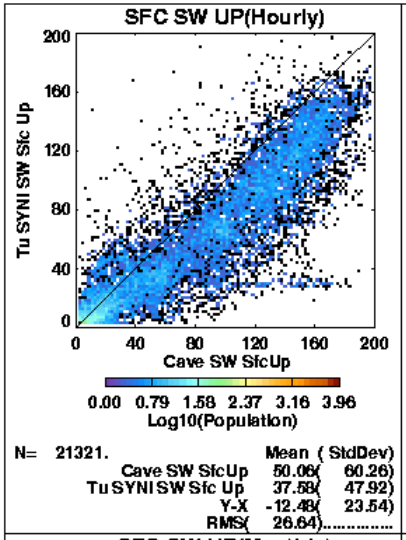


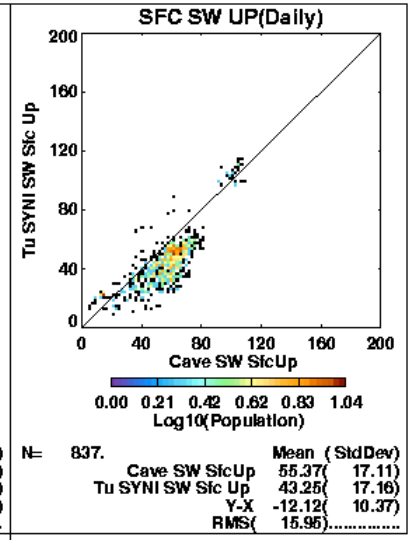
Validation 44 Site SFC SW

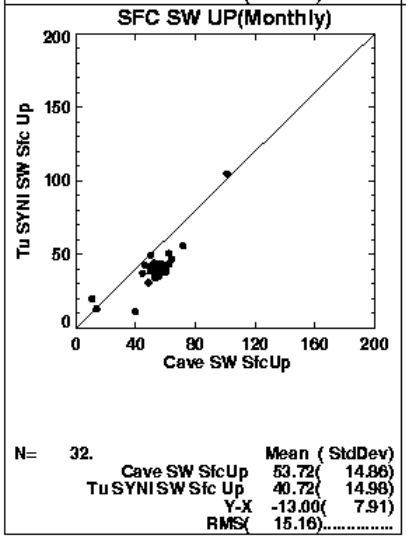
Hourly ,Daily , Monthly (Tuned)







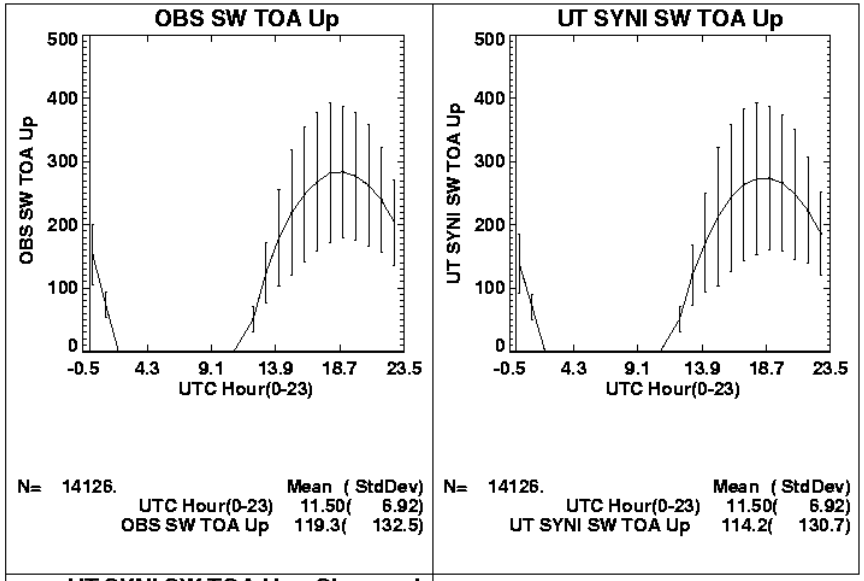


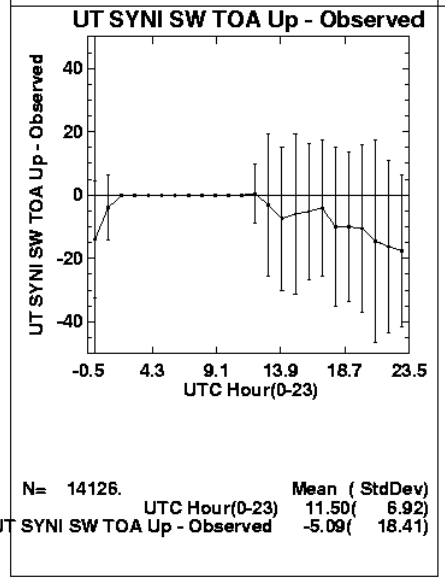


Surface Flux Validation

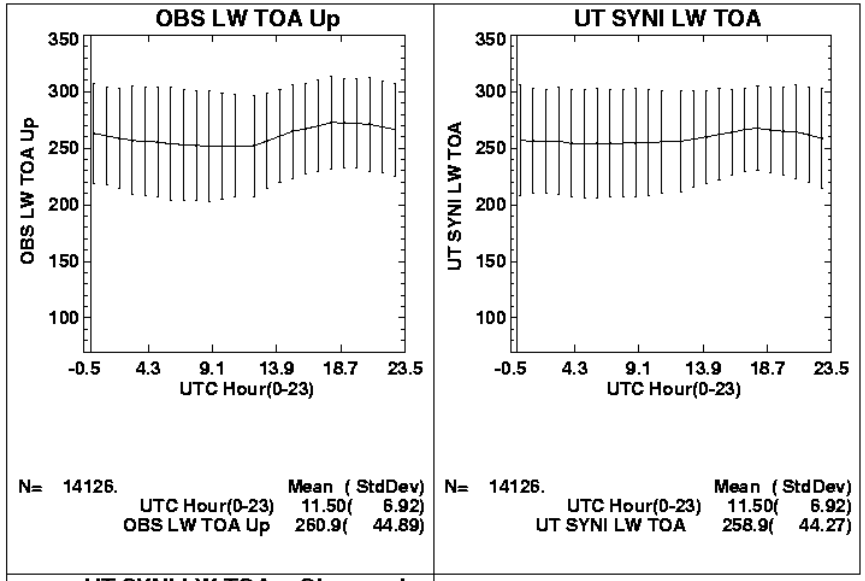
- Diurnal variability diagnosis
- Box-Whisker plots of monthly mean diurnal cycle and day to day variability.
- 19 ARM SGP Surface sites
  - SW down&up
  - LW down&up
  - 19 sites representing a few SYNI grid boxes
    - Differences are of single grid box *minus* single site

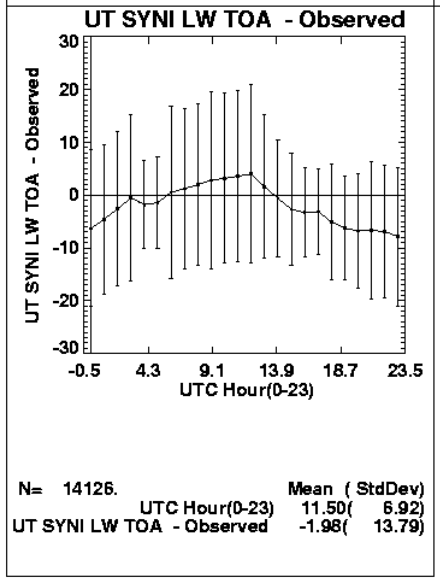
ALLSKY : SGP 19 sites



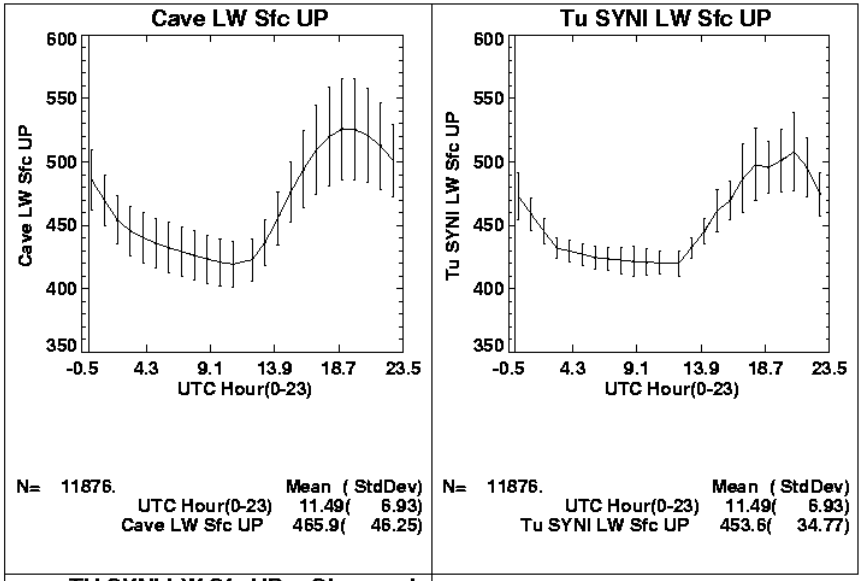


ALLSKY : SGP 19 sites



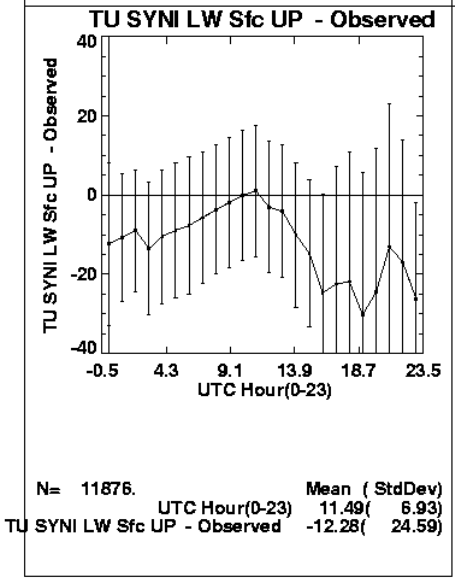


ALLSKY : SGP 19 sites



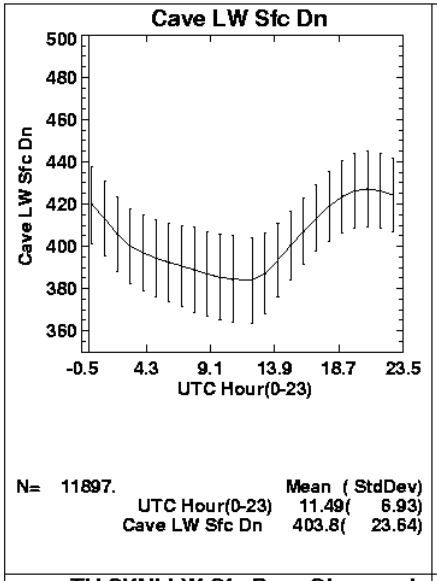
N= 11876. Mean (StdDev)
UTC Hour(0-23) 11.49(6.93)
Cave LW Sfc UP 465.9(46.25)

N= 11876. Mean (StdDev)
UTC Hour(0-23) 11.49(6.93)
Tu SYNI LW Sfc UP 453.6(34.77)

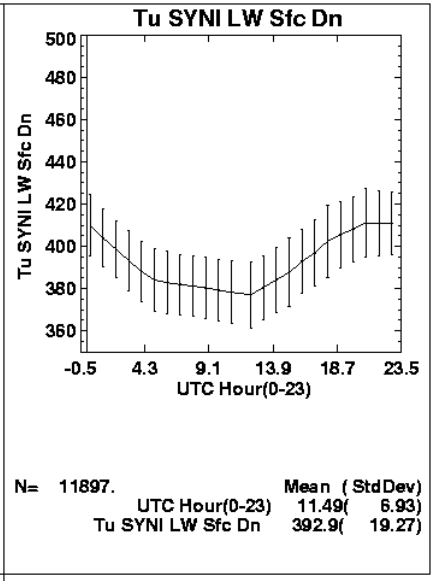


N= 11876. Mean (StdDev)
UTC Hour(0-23) 11.49(6.93)
TU SYNI LW Sfc UP - Observed -12.28(24.59)

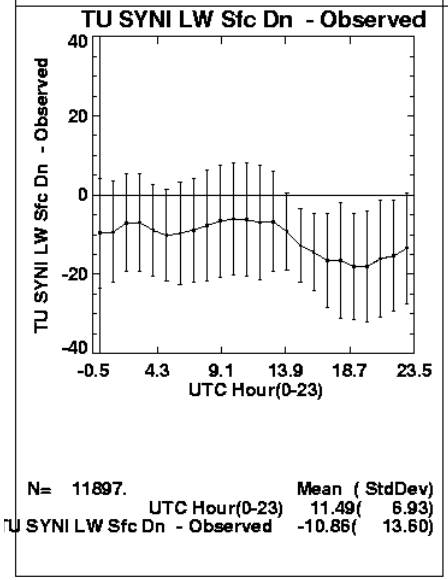
ALLSKY : SGP 19 sites



N= 11897. Mean (StdDev)
UTC Hour(0-23) 11.49(6.93)
Cave LW Sfc Dn 403.8(23.64)

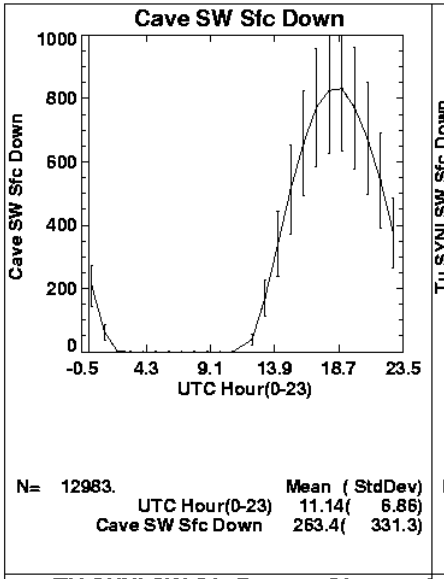


N= 11897. Mean (StdDev)
UTC Hour(0-23) 11.49(6.93)
Tu SYNI LW Sfc Dn 392.9(19.27)

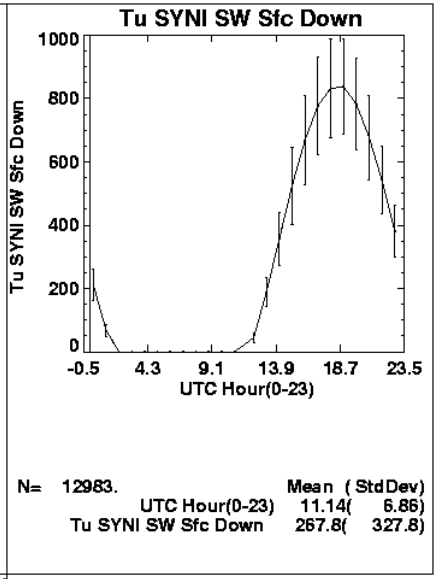


N= 11897. Mean (StdDev)
UTC Hour(0-23) 11.49(6.93)
TU SYNI LW Sfc Dn - Observed -10.86(13.60)

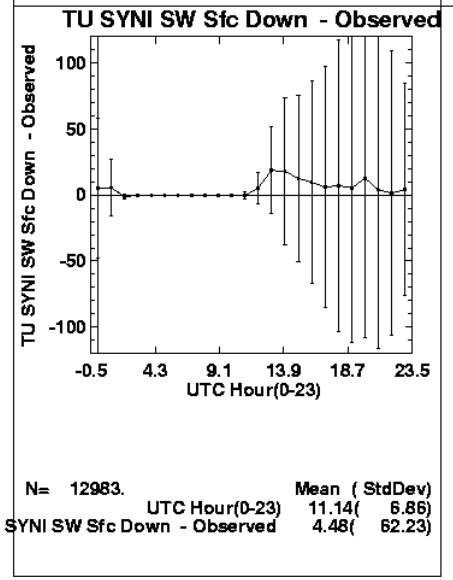
ALLSKY : SGP 19 sites



N= 12983. Mean (StdDev)
UTC Hour(0-23) 11.14(6.86)
Cave SW Sfc Down 263.4(331.3)

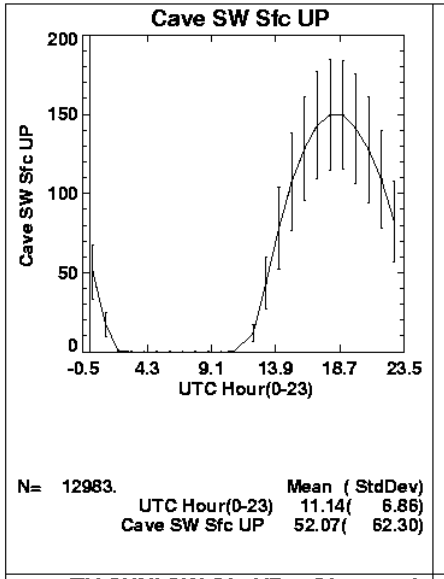


N= 12983. Mean (StdDev)
UTC Hour(0-23) 11.14(6.86)
Tu SYNI SW Sfc Down 267.8(327.8)

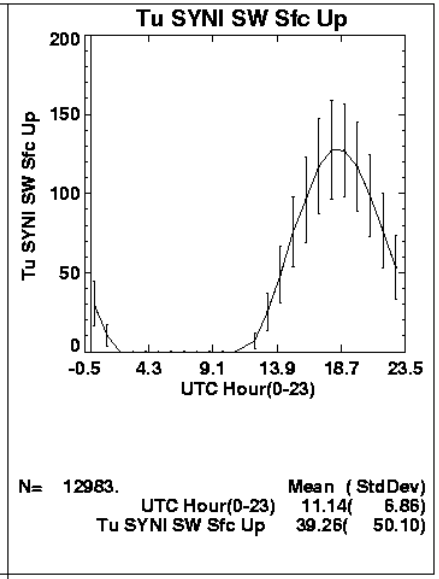


N= 12983. Mean (StdDev)
UTC Hour(0-23) 11.14(6.86)
TU SYNI SW Sfc Down - Observed 4.48(62.23)

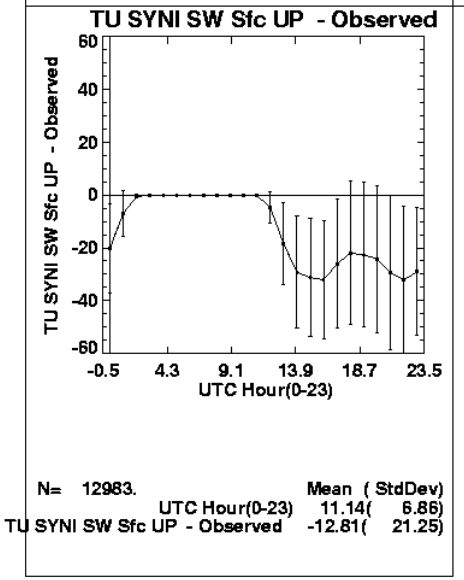
ALLSKY : SGP 19 sites



N= 12983. Mean (StdDev)
UTC Hour(0-23) 11.14(6.86)
Cave SW Sfc UP 52.07(62.30)



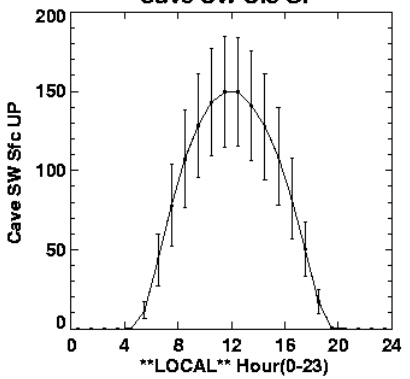
N= 12983. Mean (StdDev)
UTC Hour(0-23) 11.14(6.86)
Tu SYNI SW Sfc Up 39.26(50.10)



N= 12983. Mean (StdDev)
UTC Hour(0-23) 11.14(6.86)
TU SYNI SW Sfc UP - Observed -12.81(21.25)

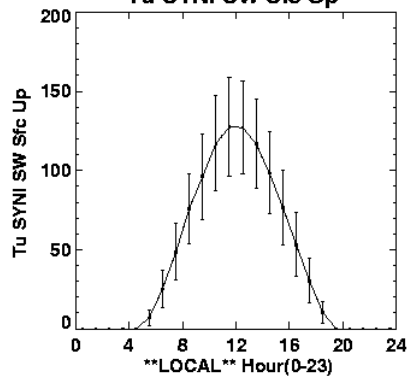
ALLSKY : E13

Cave SW Sfc UP



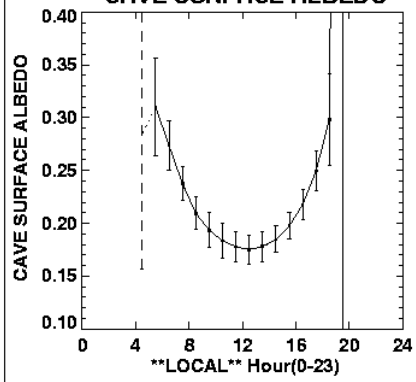
		Mean	(StdDev)
N=	12983.		
	LOCAL Hour(0-23)	11.52(	7.13)
	Cave SW Sfc UP	52.07(	62.30)

Tu SYNI SW Sfc Up



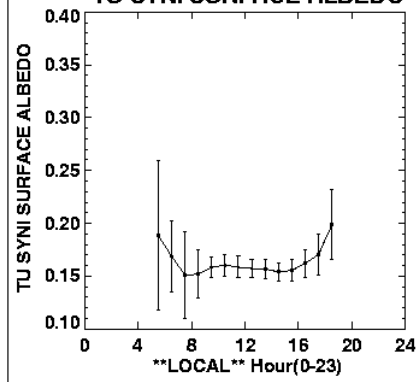
		Mean	(StdDev)
N=	12983.		
	LOCAL Hour(0-23)	11.52(	7.13)
	Tu SYNI SW Sfc Up	39.26(	50.10)

CAVE SURFACE ALBEDO



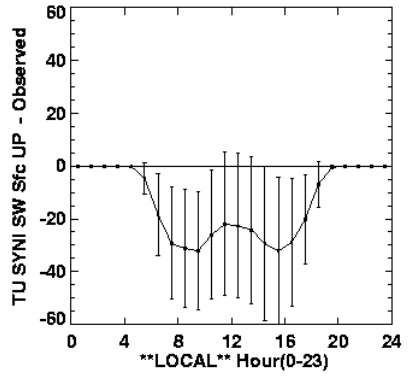
		Mean	(StdDev)
N=	647.		
	LOCAL Hour(0-23)	10.78(	3.69)
	CAVE SURFACE ALBEDO	0.229(	0.309)

TU SYNI SURFACE ALBEDO



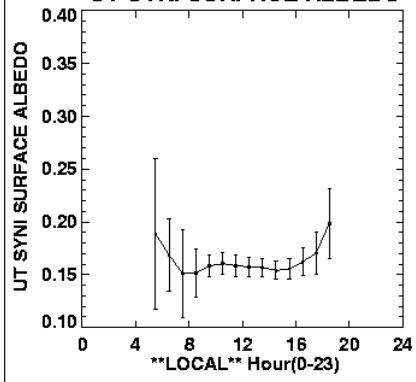
		Mean	(StdDev)
N=	635.		
	LOCAL Hour(0-23)	10.74(	3.57)
	TU SYNI SURFACE ALBEDO	0.161(	0.028)

TU SYNI SW Sfc UP - Observed



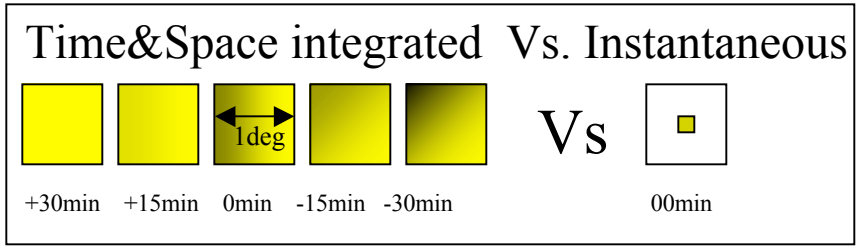
		Mean	(StdDev)
N=	12983.		
	LOCAL Hour(0-23)	11.52(	7.13)
	TU SYNI SW Sfc UP - Observed	-12.81(	21.25)

UT SYNI SURFACE ALBEDO

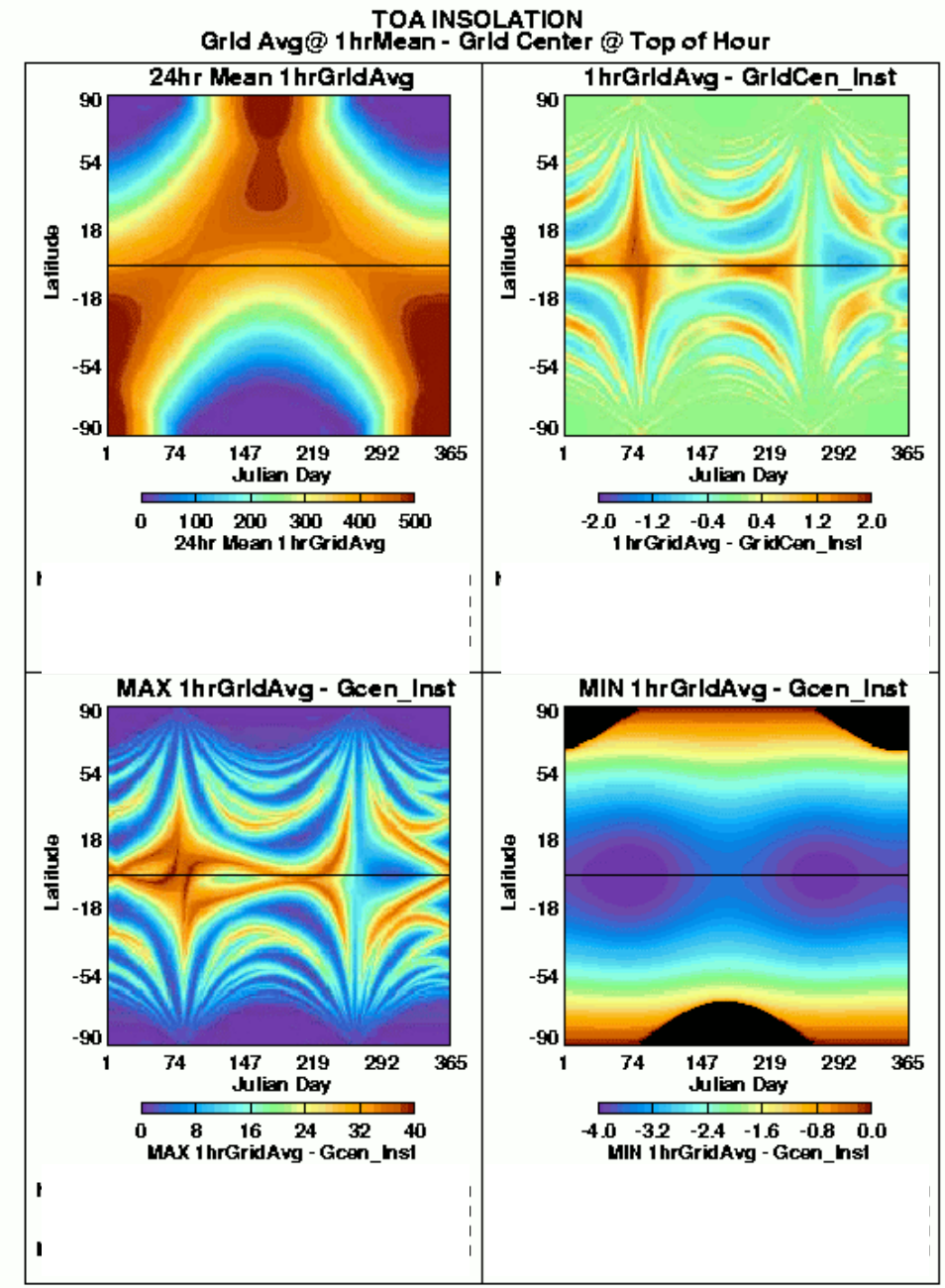


		Mean	(StdDev)
N=	635.		
	LOCAL Hour(0-23)	10.74(	3.57)
	UT SYNI SURFACE ALBEDO	0.161(	0.028)

Getting Insolation correct?



- GRIDCENTER @TopofHour= Insolation at center of gridbox at top of hour
- GRIDAVG@1hrmean = Insolation *integrated* over 1x1degree gridbox over +/-30 minutes around top of hour
- We will adjust sun angle for instantaineous RT computation to represent GRIDAVG@1hrmean



Other minor modifications before “Edition” Release

- Using Oblate Sphereoid Earth
  - 1365./4.0000 = 341.25 Wm^{-2} Sphere
  - 1365./4.0045 = 340.87 Wm^{-2} Oblate Sphereoid (max diff at 45n/s)
- Twilight Correction
  - Tiny addition of energy to sun rise/set hourboxes
  - Refraction was looked into but is different at toa & sfc
- Airmass Correction to Plane Parallel RT

u0 = Cos(SZA)

Airmass PP = 1.0/u0

AirmassCurvE = Re/h * (sqrt(u0*u0 + 2.0*(h/Re) + (h/Re)* (h/Re))- u0

Reduces pathlength thru atmosphere at low sun , less absorption.